MONITORING OF LAND USE / LAND COVER AND BIOMASS CHANGES OF PEDDAKALVAPALLE WATERSHED BY REMOTE SENSING AND GIS

Thesis submitted in part fulfillment of the requirements for the degree of Master of Engineering (Agricultural Engineering) in Soil and Water Conservation Engineering to the Tamil Nadu Agricultural University, Coimbatore-641003

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CERTIFICATE

This is to certify that the thesis entitled "**MONITORING OF LAND USE / LAND COVER AND BIOMASS CHANGES OF PEDDAKALVAPALLE WATERSHED BY REMOTE SENSING AND GIS**" submitted in partial fulfilment of the requirements for the degree of **MASTER OF ENGINEERING (AGRICULTURAL ENGINEERING) IN SOIL AND WATER CONSERATION ENGINEERING** to the Tamil Nadu Agricultural University, Coimbatore is a bonafide record of research work carried out by **Mr. N.T. SUDARSHAN NAIDU** under my supervision and guidance and no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

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MONITORING OF LAND USE / LAND COVER AND BIOMASS CHANGES OF PEDDAKALVAPALLE WATERSHED BY REMOTE SENSING AND GIS

By

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Information on changes in natural resources in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental studies, economic production, etc. Presently the availability of information on land use/land cover is not only adequate, but also it does not provide an upto date information on the changing land use pattern and processes. These maps soon become outdated with passing of time, particularly in the rapidly changing environment. In recent years, availability of multi-spectral, multi-temporal and multi-spatial remote sensing data proved to be rapid, cost effective and provides timely information. Monitoring of land use/land cover and biomass changes by using remote sensing and GIS was carried out to holistically assess the changes that have taken place over a period of time in Peddakalvapalle watershed.

Peddakalvapalle watershed is located in Chittoor District, Andhra Pradesh and falls in the Southern agro-climatic zone of Andhra Pradesh. The total

geographic area of watershed is 8241.39 ha and lies between 14°0' to 14°10' North latitudes and 78°35' to 78°45' East longitudes. The soil type of the watershed is red sandy loam. The moisture holding capacity of the soil is low and considerable area comes under rock outcrops. The average rainfall of the watershed is also low i.e. 730.04 mm.

Indian Remote Sensing (IRS) 1C/1D data for the watershed corresponding to 1997 and 2002 were analysed. The images were classified into different land use/land cover categories using supervised classification by Maximum Likelihood Algorithm. They were also classified into different biomass levels using Normalised Difference Vegetation Index (NDVI) approach.

The results indicated that the area under water bodies and irrigated lands increased by 18.06 ha (0.21%) and 486.48 ha (5.9%) respectively. The area of *kharif* season lands increased by 657.62 ha (7.98%) due to the fact that more areas of waste lands and scrubs were brought into cultivation.

This increase in the area may be attributed to better utilization of surface and ground waters, adoption of soil and water conservation practices, changes in cropping pattern, introduction of hybrid varieties, use of fertilizers and pesticides, etc. The area under wastelands, scrub and forest decreased by 89.08 ha (1.08%), 517.63 ha (6.28%) and 128.23 ha (1.56%) respectively.

Vegetation vigour of the area was classified into five classes using NDVI. Substantial increase in the area under very high, high and medium biomass levels was observed. The areas under very high, high and medium biomass levels increased by 244.98 ha (2.97%), 319.92 ha (3.88%) and 552.14 ha (6.7%) respectively.

The cost of monitoring of land use and biomass changes in Peddakalvapalle watershed by remote sensing and GIS worked out to Rs.7.30/ ha while that of conventional methods was Rs.16.00/ha and also needed very short time. Thus, monitoring of a watershed by using remotely sensed data in cheap, rapid, accurate and reliable with repetitive coverage.

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LIST OF ABBREVIATIONS

ADS	-	Arc Digitizing System
AVHRR	-	Advanced Very High Resolution Radiometer
BES	-	Bureau of Economics and Statistics
DAS	-	Days After Sowing
DBTM	-	Digital Basement Terrain Model
DPAP	-	Drought Prone Area Programme
EASI	-	Engineering Analysis and Scientific Interface
ET	-	Evapotranspiration
FCC	-	False Colour Composite
GIS	-	Geographic Information System
ha	-	hectare
IMD	-	Indian Meteorological Department
IMSD	-	Integrated Mission for Sustainable Development
INSAT	-	Indian National Satellite
IRS	-	Indian Remote Sensing Satellite
ISRO	-	Indian Space Research Organisation
LAI	-	Leaf Area Index
LISS	-	Linear Imaging Self Scanning
MIR	-	Middle Infrared
MXL	-	Maximum Likelihood Algorithm
NDC	-	National Data Center
NDVI	-	Normalised Difference Vegetation Index
NIR	-	Near Infrared
NNRMS	-	National Natural Resources Management System
NRSA	-	National Remote Sensing Agency
NWDPRA	-	National Watershed Development Programme for Rainfed Agriculture
PACE	-	Pixel Analysis Correction Enhancement
PAM	-	Panchromatic
q	-	Quintal
RRSSC	-	Regional Remote Sensing Service Centre
SAC	-	Space Application Centre
SAR	-	Synthetic Aperture Radar
SCS	-	Soil Conservation Service
SOI	-	Survey of India
TES	-	Technology Experiment Satellite
TM	-	Thematic Mapper
USDA	-	United States Department of Agriculture
USLE	-	Universal Soil Loss Equation
VNIR	-	Visible / Near Infrared
WiFS	-	Wide Field Sensor

INTRODUCTION

CHAPTER-I

INTRODUCTION

Dry land farming in India accounts for 63% of the cultivated land of 144 M ha. These dry lands are impoverished, deficient in plant nutrients and suffer from various forms of land degradation. The crop production on these lands is dependent entirely on the natural precipitation, which is highly erratic in terms of spatial and temporal distribution during the crop growing season. Dry land farming is also affected by the socio-economic conditions of small holdings, expensive credit, low fertilizer use and poor infrastructure.

To address the problem of dry lands, watershed is considered as an appropriate geo-hydrological unit in which rainfall occurring on the highest point of the area drains through a common point.

The growing pressure of population coupled with increasing variety of demands made on natural resources, has brought extra pressure on the availability of land resources all over the country (Rao *et al.*, 1996). Information on changes in natural resources in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental studies, economic production etc. (Anonymous, 1989).

Today, the availability of information on land use/land cover in the form of thematic maps, records and statistical figures is inadequate which does not provide an upto date information on the changing land use pattern and processes.

Conventional ground methods of land use mapping are labour intensive, time consuming and are done relatively infrequently. These maps soon become outdated with passing of time, particularly in a rapidly changing environment. In recent years, the remote sensing techniques have proved to be rapid, cost effective and provides timely information with the capability of repetitive coverage of a given area/zone once in 5 to 22 days. Availability of multi-spectral, multi-temporal and multi-spatial remote sensing data from space platform for the given area of interest has revolutionised in providing the vital inputs to the mapping, monitoring and management of basic natural resources like vegetation, water resources, soils, mineral resources, ocean resources, etc.

The remotely sensed data has the unique advantage of providing synoptic view/large area coverage which helps in obtaining the proverbial "birds eye view" of the features. Satellites, which orbit around the earth, provide a vantage point to observe, measure, map and monitor the earths natural resources. Remotely sensed data potentially offer a rich source of information about conditions on the earth surface that change over time. Measuring and evaluating changes in a landscape over time is an important application of remote sensing. With the launch of indigenous Indian Remote Sensing Satellites (IRS), data is available regularly at frequent intervals over the same region from 1988 onwards in the country.

The repetitive coverage of the satellite provides us an excellent opportunity to monitor the land resources and evaluate the land cover changes through a comparison of images acquired for the same area at different times.

Changes like increased area under cultivation, conversion of annual crop land to horticulture, change in surface water area and levels, afforestation, soil reclamation, etc. could be monitored through satellite remote sensing.

Presently IRS-1B, IRS-P2, IRS-P3, IRS-1C and IRS-1D satellites are operational. These satellites have sensors in the visible and infrared region and are good for assessing the size and shape of the watershed, type of vegetation, crop vigour, growth monitoring, green biomass, soil and water characteristics of a watershed. However, the sensors have a constraint of not able to sense the earth's surface below the clouds. This constraint is mainly during the *kharif* season. Fortunately, the technology of microwave remote sensing has advanced well and today we have access to Synthetic Aperture Radar (SAR), an active microwave remote sensor, capable of looking through the clouds. India will have an operational satellite borne SAR sometime in the near future.

Peddakalvapalle Watershed located in Chittoor District, Andhra Pradesh was selected for the study. Many efforts are made in the watershed by various departments and farmers to improve the conditions of the watershed. It is necessary to holistically assess and evaluate the longterm effects and note the changes that have taken place over a period of time through reliable methods. The objectives of the study are : -

1) To delineate the land use/land cover categories of the selected watershed for two periods.

2) To generate Normalised Difference Vegetation Index (NDVI) for the watershed for both the periods.

3) To compare the classified outputs to derive information on changes with respect to increase/decrease in different land use/land cover categories.

4) To compare NDVI images to derive the information on changes with respect to vigour/biomass.

5) To interpret and derive the change statistics to evaluate the magnitude and direction of transformation.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The advent of remote sensing technology service in the past three decades, has provided satellite images for innovation and monitoring of natural resources in India. This remote sensing technology has proved to be rapid and provides timely information with repetitive coverage of a given area in 5 to 22 days. Several remote sensing application projects of the national, regional and local levels have been taken up for research and development and programme implementation. Some of the reviews of previous works related to these are presented in this chapter under following headings.

2.1 Remote sensing application in agriculture and natural resource management

2.2 Identification of crops and acreage estimation

2.3 Land use/land cover classification and change detection by using remote sensing and GIS

2.4 Change detection in the watersheds by conventional methods

2.1 Remote Sensing Application in Agriculture and Natural Resource Management

A study was undertaken to determine priority classes of sub-watersheds in a part of song river watershed, based on spatial erosional soil loss estimates using IRS-1A LISS-II digitally classified physiography – soil – land use/land cover map, terrain slope information and rainfall – climatic data following USLE. The results indicated that out of fifteen sub-watersheds, nine sub-watersheds belong to high to very high priority classes covering 36.2 per cent area of the watershed. Rest six sub-watersheds covering 63.8 per cent area of the watershed were classified as low to moderate priority categories (Saha *et al.*, 1992).

A study was conducted for assessing the potential of remote sensing data in providing input to the SCS model developed by the USDA and exploring the possibilities of improving the model through implementation of a GIS package. The results demonstrated the capability of Landsat data in providing multithematic maps which could be used to provide input to runoff model. Implementation of the GIS package enabled computation of runoff potential indices on pixel-by-pixel basis imparting physically distributed approach to the model (Das *et al.*, 1992).

Drainage pattern of Ranigani coal field basin was mapped by using Landsat TM and IRS-LISS-II data and their characteristics were interpreted in terms of basin morphology, surface materials and underlying rock types (Srivatsava and Mitra, 1995). They reported that the drainage system of the region was composed of 3 perennial rivers with 15 ephemeral nalas and jhors which as a whole flows on recent pedeplain basin. They concluded that the nalas and jhors hold sufficient amount of water during monsoon and therefore by effective planning and management, surface water resources could be enhanced in the region.

An attempt was made to analyse cropping system of Bardhawan district, West Bengal by using IRS-1C Wide Field Senior (WiFS) data (Panigrahy *et al.*, 1995). They reported that it was feasible to derive accurate information on cropping pattern, crop rotation, crop duration, progress of harvest, crop growth profiles and annual crop acreages using multidate data. It was observed that even a seven to eight day interval of data acquisition during critical growth periods significantly affected classification and identification accuracy.

The flood affected areas in Sirsa District, Haryana were mapped during 1993 using IRS LISS-II data. Two categories of flood affected areas viz., standing water and wet areas were identified. The flood water was standing in an area of 1967.25 ha while wet areas covered 16773.75 ha. Silting of Ottu reservoir, mismanagement of river banks and bunds and lack of drainage system were identified as major causes of floods. Three management practices were suggested to contain the fury of floods (Kundu and Mothikumar, 1995).

A study was undertaken to delineate waterlogged areas in the Tawa command using IRS-1A LISS-I data by Choubay (1997). The results indicated that in October, 1980 an area of 80 km^2 was affected by waterlogging and about 140 km^2 area was sensitive for waterlogging, where the water table was between 0 and 3 m.

A study was undertaken to estimate regional scale evapo-transpiration using satellite derived albedo and surface temperature. Satellite data was used in determining the surface emissivity over heterogeneous areas by taking Normalized Difference Vegetation Index (NDVI) as modulating parameter at pixel resolution. The estimated emissivity values were used to find surface temperature. Landsat data and some ground meteorological data were used in an energy balance model for estimating surface albedo and evapotranspiration. The ET values derived from the model were in good agreement with the ground observations over the area (Kant and Badarinath, 1998).

Geomorphologic map prepared using the remote sensing techniques and conventional methods was used to assess groundwater prospects. The geomorphic units delineated were denudational, fluvial and coastal. The study indicated that the fluvial and rolling plains were promising zones for groundwater occurrence. The denudational land forms were not considered as groundwater potential zones (Rao and Reddy, 1999).

A multi-thematic analysis based on different physical factors was adopted to generate integrated maps on erosion proneness as well as on critical slope under a GIS platform for terrain evaluation. The spatial data on erosion proneness demonstrated that 17.62 km^2 area needed careful attention for eco-restoration. In the critical slope map four land stability classes are demarcated. Temporal change in the drainage network over a period of four decades as well as the extent of loss in the perennial status of tributaries were recorded to evaluate the land form changes (Babu *et al.*, 1999).

The remote sensing, geophysical, DBTM (Digital Basement Terrain Model) and GIS techniques were used for providing scientific database for sustainable usitlisation of water resources in watershed perspective. Analysis indicated that surface and ground water resources had potential to irrigate 53 per cent of geographical area of the watershed. Feasibility of large-scale development of groundwater through dug well was possible only in 2 per cent of the watershed.

The study also helped in prioritizing the water resource development activities (Kumar, 1999).

Land degradation in Puruliya district was assessed using remote sensing techniques. The results indicated that 31.8 per cent area of the district suffers from one or the other kind of land degradation. Water induced soil erosion was the major problem which accounted for 31.3 per cent of the district. The open scrub land were most vulnerable to soil erosion followed by agricultural lands. Forest lands were least affected by degradation. The land degradation was quite significant in undulating plain and plateau lands (Saini *et al.*, 1999).

Major physiographic units in an arid watershed of Jodhpur district were identified and mapped by using IRS LISS-II data. Based on image characteristics and field traverses, seven major physiographic units were identified. Based on physiographic variation and soil or site characteristics such as texture, depth, slope, erosion and underneath substrata, 41 soil mapping units were identified and mapped. Final physiography, soil, slope, drainage and land use maps were prepared. Taxonomically, the soils of the watershed were classified and land suitability for various mapping units in the watershed were assessed on the basis of soil physico-chemical characteristics (Khan and Singh, 2000).

Degraded lands in Vidarbha region of Maharashtra were assessed using remote sensing technique. District-wise land degradation maps were generated by using IRS-IA data supported by limited ground survey. It was observed that degraded lands occupy nearly 2.1 M ha or 21.5 per cent of the total geographical area. Among the major land forms, the largest degraded area was associated with undifferentiated plain accounting for 1.1 M ha or 72 per cent of the total area of region, which was mostly under cultivation. The problem of degradation was more rampant in agricultural lands than forest/waste lands (Ghatol and Karale, 2000).

Efficacy of irrigation management of wheat and mustard crops grown in Western Yamuna canal command area was determined from agro-climatic data merged with maximum likelihood classified (MXL) satellite image and from irrigation scheduling efficiencies. For computing irrigation scheduling efficiencies, amount of water supplied at different growth stages, soil water depletion and crop water received were taken into account. Agro-meteorological data in combination with MXL classified crop map approximated the deficiency of applied irrigation amount compared to requirement. Irrigation at 35-80 days after sowing (DAS) for two times of application, 30-60-90 DAS for three, 21-50-80-110 DAS in case of four and 20-45-70-90-120 DAS in case of five irrigations yielded better scheduling efficiencies for wheat than other times of applications in all soil associations (Raut *et al.*, 2001).

The overall soil erosion potential of the Ivsikazi area, South Africa was determined using the bare soil index (BSI) derived from satellite imagery and geo-spatial information from various sources in a GIS environment. By integrating a BSI map with a natural soil erosion potential map, an indication of the soil degradation was obtained. Land use patterns were also used to identify the specific human activities that caused the most extensive soil erosion (Wentzel, 2002).

2.2 Identification of Crops and Acreage Estimation

Soil and land use survey of Mewat area, Haryana was carried out using areal photographs. Four major physiographic units were recognized and the land use was studied in relation to these units. Of the total area of 161,103 ha, 13,1637 ha (81.72%) was cultivated. Of this 75,967 ha (47.16%) was irrigated and 55,670 ha (34.56%) was unirrigated. Under uncultivated area, barren lands covered 14,224 ha, forests occupied 8463 ha, settlements covered 3300 ha, water bodies occupied 1312 ha and roads, railway lines and drains constituted 2167 ha (Natarajan *et al.*, 1986).

Total wheat area in Punjab for the year 1986-87 and 1987-88 was estimated using single date lands at MSS digital data and stratified random sampling technique (Sridhar *et al.*, 1988). They reported that the results for the state were within 5 per cent of the corresponding BES estimates for both the years.

Landsat MSS data of Sariska National Park and its surroundings was digitally classified into various land use forest type classes. Forest land was about 52% of the study area and four forest types, namely Anogneisses Pendula, Baswellaa serrata, mixed Anogeissces – Gutea and mixed Acawazizyphus and occupied an area of 28.47, 6.60, 18.60 and 9.70 per cent, respectively. The area under National Park was 51.27 per cent of the study area and about 61 per cent of the park area was under tree cover vegetation (Tiwari *et al.*, 1990).

Supervised classification technique with MXL algorthium was used to assess the forest in the region extending between Lucknow through Allahabad to Mirzapur city in UP (Kachhwaha, 1990). He identified and mapped 5 different categories of forests by computer processing of Landsat-3 MSS data. The area under each category was also computed.

The area under *rabi* vegetable crops in Hoshiarpur district, Punjab was estimated using IRS-1A LISS-I data. The area under vegetable crops in the district was found as 6.17% of the total geographical area. The area under vegetable crops closely matches with the figures supplied by the Department of Horticulture, Punjab (6% of the district area) (Dhaliwal *et al.*, 1992).

A study on estimation of pre-harvest acreage of rapeseed/mustard crop using IRS LISS-II data was carried out for the year 1992-93 in major mustard growing districts of Assam. MXL algorithm using four bands of LISS-II were able to discriminate mustard from other vegetables with more than 95% accuracy (Sharma *et al.*, 1993).

IRS LISS-II data of Jalpaiguri district, West Bengal was digitally analysed to differentiate three density classes of forest, viz., dense/closed forest, open forest and degraded forest. Forested and non-forested areas were classified through supervised classification techniques using MXL algorithm. The forest cover of the district was found to be 1420.89 km^2 (22.82%) agriculture area (45.20%) and tea gardens (10.49%). The accuracy of the classified output was estimated to be 90 per cent for forest areas and 85 per cent in case of other land use/land cover classes (Sudhakar *et al.*, 1994).

Social forestry plantations in Matar taluk, Gujarat were delineated using digital analysis of IRS-IA, LISS-II data. Supervised maximum likelihood classification technique was used to categorise the various plantations. The classified output yielded three categories of plantations viz., *Eucalyptus spp.*, *Acacia spp.* and *mixed spp.* and the area covered by each category constituted 3.4, 0.6 and 1.9 per cent respectively of the total geographical area (Sugumaran *et al.*, 1994).

Rice identification and acreage estimation for Midnapur district was carried out by Kalubarme and Vyas (1988) using single date Landsat MSS data. Maximum likelihood supervised classification was used and the results showed that 58.08 per cent of geographical area was under rice against 54.56% estimated by the Department of Agriculture. The supervised classification of systematically sampled data resulted in 58.07 per cent rice acreage as against 58.08 per cent obtained from image data analysis.

Using IRS-IC LISS-II data sets acreage estimation and condition monitoring of sugarcane crop were carried in part of Krishna district, AP. The acreage estimated was 12,764 and 15,211 ha during 1997-98 cane seasons respectively by MXL algorithm. The condition assessment was attempted using NDVI and the results showed a significant improvement in cane development (Rao *et al.*, 1999).

Medhav *et al.* (1993) carried out district wise wheat acreage estimation in 22 districts of North Bihar for 1992-93 using IRS LISS-I digital data. Total acreage and production of wheat in 22 districts were estimated at 1.316 M ha and 2.328 Mt respectively using stratified random sampling approach.

The extent and distribution pattern of arecanut plantations in Sirsi Taluk, Karnataka were studied using IRS LISS-II data. The plantations were found to exhibit perfect zonality, distinct structure and contrasting tonal characteristics and thereby enabling their differentiation from other land use/land cover categories. The area under areca plantations was estimated to be 3,030.30 ha which was about 2.29 per cent of the total geographic area of the taluk (Hegde *et al.*, 1994).

2.3 Land Use/Land Cover Classification and Change Detection by using Remote Sensing and GIS

Using remote sensing technology land use/land cover changes for a part of Gohparu block, M.P. over a period of 30 years were studied. The loss of vegetation cover was estimated to be 22 and 14 per cent of the land was found to have been transformed into waste land between 1967 and 1996. Overall rate of change was found to be 1.8 per cent per year during this period (Jaiswal *et al.*, 1994)..

A large change in land use in Dewan block of Ludhiana District using IRS-IB LISS-II data for the year 1993, IRS PAN data for 1997 and SOI topo maps for 1964 was studied by Minakshi *et al.* (1999). The agricultural area was reduced from 94.4 per cent in 1964 to 90.26 per cent in 1997, while the area under rural settlements increased from 312 ha in 1964 to 1,162 ha in 1997. The extra area of about 169 ha under wasteland was added during the period under study making total wasteland area to about 400 ha in 1997.

Land use/land cover clusters in Tiruvalluvar area, Tamil Nadu were mapped during the years 1986 to1990 using LANDSAT-5 and IRS-1A LISS-II images. The built up area and the agricultural land use extensions were on upward trend, whereas the area under forest and wasteland showed a declining trend caused by increasing population and related trends in other parameters (Palaniyandi and Nagarathinam, 1997).

Land use change of Mumbai city was studied by using SOI topo maps and Landsat TM digital data. In the last 70 years 55 per cent reduction in forest/agricultural land and 300 per cent increase in built up land was observed. The change was affected the natural drainage system of the city, causing floods during monsoons (Samout and Subramanyam, 1998).

A study on monitoring and evaluation of 20 watershed of Karnataka was taken up using remote sensing and GIS. The overall improvement in the land and water resources development was observed varying from 7 to 27%. The study indicated increased area under forest/horticulture plantation, expansion of area under cultivation, changes in cropping pattern, change in waterspread area, reclamation of waste lands for productive use (Anonymous, 1998).

A study was carried out to monitor the spatial change in the extent of sodic lands consequent upon reclamation efforts in Raibareli District, Uttar Pradesh. IRS-1C LISS-III and Landsat-TM data were used and by using ARC/INFO GIS, a change detection map was prepared. It was reported that a total of 69% of the sodic lands that were lying barren in 1986 have been brought under cultivation during 1997. The extent of barren sodic lands reduced from 50,363 in 1986 to 23,197 ha in 1997 (Verma and Singh, 1999).

Temporal changes in land use/land cover using multi-temporal satellite data in Mahi Right Bank canal command was studied from 1988 to 1997 (Brahmabhatt *et al.*, 2000). The land use/land cover change was maximum in a distributary situated in highly urbanized zone where built up area increased from 205 ha to 868 ha. There was an increase in urban area from 281 to 460 ha in Nediad command area, causing a decrease in agricultural area. The canal command was also affected by waterlogging and salinity.

The satellite based monitoring and evaluation of NWDPRA watershed of Tamil Nadu, carried out using IRS LISS-II data indicated, increased area under cultivation both in dry and irrigated, horticulture agro-horticulture/agro-forestry, more number of water bodies, reclamation of waterlands for productive use. The study indicated a overall change from as low as 2.37 to 27.38 per cent for these watershed (Anonymous, 2000).

Multi-data satellite images for Godavari deltaic region for 25 years from 1973-99 were interpreted by Sharma *et al.* (2001). They reported that the area under intensive agriculture increased from 1,459 to 3,500 km^2 and the extent of wetland from 368 to 648 km^2, while the seasonal fallow decreased by 2,321 km^2.

Studies on spatial distribution of the different forests during 1970 to 1999 using integrated remote sensing and GIS techniques revealed that the area under forests in the Kalarani Round progressively reduced with time. In 1970 forest area was 22.75 km^2 in 1989, it was 15.34 km^2 and in 1999 and it was only 12.93 km^2 (Karai *et al.*, 2001).

Land use/land cover distribution on Lang Kawi Island, Malaysia was mapped using remote sensing and GIS by using Landsat TM. Maximum likelihood supervised classification was performed and the overall accuracy of the output image was 90 per cent and individual class accuracy ranged from 74 per cent for rubber to 100 per cent for paddy fields. The classified areas on the image were mainly confined to the mountainous and hilly regions on the island (Serman and Yosuf, 2001).

The vegetation dynamics and land use/land cover types of Birantiya Kalam watershed, Rajasthan were characterized and evaluated by remote sensing and GIS. The land use/land cover types identified were crop land, fallow, forest, land with scrub, land without scrub, sandy area and water body. From 1988 to 1996, seasonal fallow land increased significantly and the areal extent of water body decreased to almost half. Vegetation vigour types were classified into very poor, poor, moderate, good and very good categories. Moderate vigour type reduced from 627 to 27 per cent and poor type increased from 34 to 68 per cent (Chakraborthy *et al.*, 2001).

Land use was monitored through a nested hierarchy of land use by using Landsat TM images for the Pearl River Delta, China. Most of the land use change was conversion from agricultural land to urban areas. Results indicated that the urban areas increased by more than 300% between 1988 and 1996. Field assessment confirmed high overall accuracy of the land use change map (93.5%) and supported the use of change vectors and multidata Landsat TM imagery to monitor land use change (Seto *et al.*, 2002).

2.4 Change Detection in the Watersheds by Conventional Methods

The yield per ha in a watershed in Shivalik hills increased from 64.6 q in base year, 1981 to 81 q in the post project period, 1985 by adopting conservation practices (Agnihotri *et al.*, 1986).

According to the study conducted by Reddy and Sudha (1988) at Chevella watershed in Medak district of Andhra Pradesh and Mittemari watershed in Kolar district of Karnataka, the income from all sources were higher by Rs.463 per household at Chevella and Rs.1,046 per household at Mittemari watershed areas compared to non-watershed areas.

Hanumanthaiah and Natraj (1989) observed a radical change in land use pattern in Chinnatekur watershed area of Kurnool district in Andhra Pradesh between pre and post-watershed development period. The study revealed an increase in dry – west area, while the dry land area declined in the post watershed period. The cropping pattern showed considerable varieties with mixed cropping and new crops take red gram occupied larger area after the five year period of watershed development.

While analyzing the economic aspects of watershed programme at Chinnatekur of Kurnool district in Andhra Pradesh, Nataraj (1989) observed that there was an increase of 38% in cropping intensity on small and marginal farms in watershed project area while the increase was 74.66% on large farms.

Pagire (1989) reported that watershed development programme at Kothewadi village in Maharasthra resulted in an increase in the area under crops during both *kharif* and *rabi*. Diversification in the cropping pattern was also reported during the study period between 1984-85 and 1988-89. The gross cropped area increased by 5 per cent as against 7.5% in the base year. Similarly, the double cropped area increased from 5-10 ha to 41.76 ha.

Singh *et al.* (1989) from their study on the socio-economic impact of kandi watershed development project in Punjab concluded that there were significant shifts in land use pattern, from uncultivated to cultivated, uncultivated waste to cultivable area and from unirrigated to irrigated due to the project. The crop pattern analysis also indicated a slight shift in favour of commercial crops.

Muchkulla Nala watershed development programme resulted in complimentary land use system wherein dry land horticulture crops like mango, lime, etc. were introduced for the first time in the area. Besides, it resulted in the popularization of dairy activity in the village because of augmentation of higher fodder production. Increased area under the vegetable cover facilitated higher infiltration rate and was found to have helped in overcoming the hazards of floods during heavy monsoons (Kallur, 1991).

According to Jyothi (1991), the average income (Rs.48,285) per farm in the developed area at Maheswaram watershed was higher by 68.11% compared to that of non-watershed area (Rs.28,723).

The implementation of the Rendhar watershed project, Uttar Pradesh during 1983-89, resulted in phenomenal increase in crop productivity by 300 to 600 per cent. Cattle population, milk and fish production during that period were also increased. Milk production increased by 352.7 thousand litres during the period (Singh and Singh, 1991).

The economic anlaysis of watershed management of Anakatti region in Coimbatore district was carried out by Randhir and Ravichandran (1991). They reported that new crops like cotton and cowpea entered into the cropping system and cropping intensity increased by 12.68% due to the watershed programme.

In a study of Aravali a decrease in the waste land area from 5.4 to 10 ha and increase in rainfed area under double cropping from 125 to 601 ha after the project period was observed (Swarnalatha *et al.*, 1994).

Krishnappa *et al.* (1994) while documenting the changes in Achalu micro-watershed at Kabbanala, Karnataka, found that agricultural production increased from 15.74 t during pre-project period to 48.41 t in the post project period from an area of 28.45 ha mainly due to change in cropping pattern. Also while studying the impact of watershed development at Kabbanala watershed, they observed an increased in crop yield from 6.79 q/ha during pre-project period to 18.95/ha in post-project over a period of 4 years at Dunthur micro catchment.

The study on the impact of watershed development at Nartora watershed, Madhya Pradesh revealed that the yield of groundnut, paddy and wheat increased by 30, 25 and 10% during the post-project period compared to the pre-project period (Jolly *et al.*, 1995).

The study conducted by Rao *et al.* (1995) on the changes in oil seed production in semi-arid tropics of Andhra Pradesh revealed that yield of groundnut and sunflower were higher by 26.7 and 31.5 per cent in Chinnatekur watershed area compared to non-watershed areas on account of adoption of improved resource conservation measures under watershed project.

The DPAP watershed development project in Maharashtra proved to be effective in the conservation of soil and water resources as a result of which the proportion of the irrigated area and the cropping intensity increased by 30 and 53% respectively. The substitution of high value crops for the low value crops was pronounced in the watershed area.

The watershed development in Kuthanagere, Karnataka State brought about an appreciable change in land use pattern by introducing land capability based alternative systems like silvi-pasture, silvi-horti-pasture, horti-pasture and agri-horti. The yield of major corps were higher by 35 to 40 per cent in the area (Kumar, 1998).

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

This chapter was arranged in two parts. The first part deals with the general description of remote sensing and GIS. It includes the information about the remote sensing applications in agriculture, availability of satellite data in India and the software available for image analysis. The second part deals with the specific works carried out with respect to the watershed selected.

3.1 Remote Sensing and Geographic Information System (GIS)

Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer, 2000). Remote sensing employs electromagnetic energy, such as light, heat and radio waves, as the means of detecting and measuring target characteristics.

3.1.1 Electromagnetic energy

Electromagnetic energy refers to all energy that moves with the velocity of light in a harmonic wave pattern. Electromagnetic energy that encounters matter, whether solid, liquid or gas is called incident radiation. Interactions with matter can change the following properties of the incident radiation, intensity, direction, wave length, polarization and phase. The science of remote sensing detects and records these changes. The resulting images and data were then interpreted to determine the characteristics of the matter that interacted with the incident electromagnetic energy.

The reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected. This is measured as a function of wave length and is called spectral reflectance. Mathematically it is given as,

$$\text{Spectral reflectance} = \frac{\text{Energy of wavelength } \lambda \text{ reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident upon the object}} \times 100 \qquad (3.1)$$

This spectral reflectance is expressed as a percentage. A graph of spectral reflectance of an object as a function of wavelength is termed a spectral reflectance curve. The configuration of spectral reflectance curves gives us insight into the spectral characteristics of an object and has a strong influence on the choice of wavelength region(s) in which remote sensing data are acquired for a particular application.

During interactions between electromagnetic radiation and matter, mass and energy are conserved according to basic physical principles. Figure 3.1 illustrates the five common results of these interactions. The incident radiation may be transmitted, absorbed, emitted, scattered or reflected (Sabins, 2000).

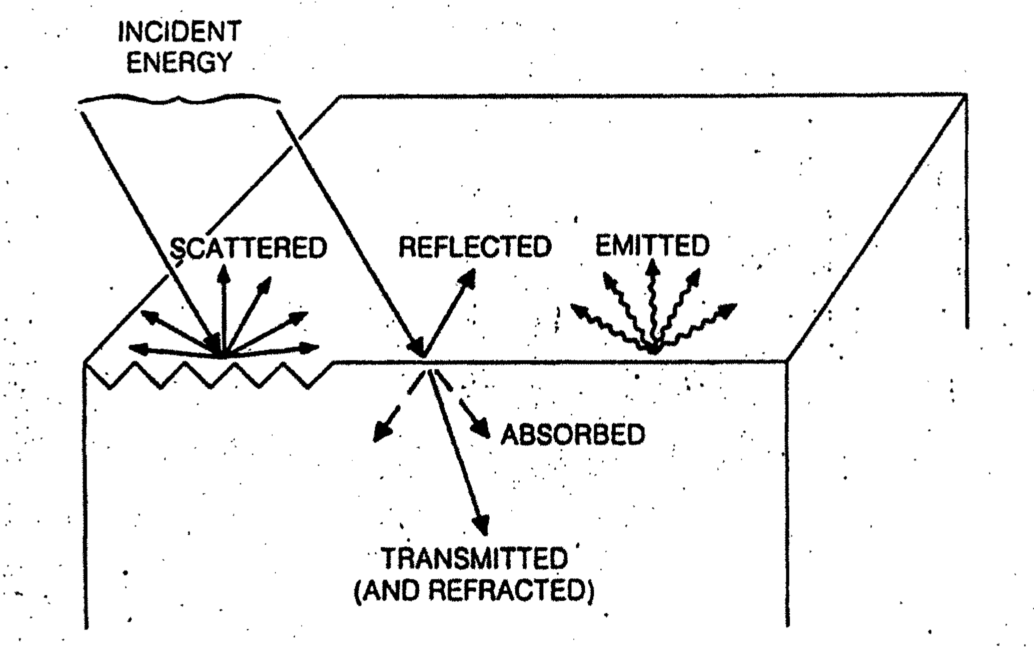


Fig.3.1: Interaction between electromagnetic energy and matter

(Sabins, 2000)

3.1.2 Applications of Remote Sensing in Agriculture

a. Crop production forecasting

Crop production forecasting comprises identification of crops, acreage estimation and forecasting yield. Crop identification and discrimination is based upon the fact that each crop has a unique spectral signature. Spectral response of a crop canopy is influenced by the leaf-area index (LAI) and per cent ground cover, growth stage, differences in cultural practices, stress conditions and canopy architecture. Background soil/water is an important influencing factor. Each crop has its own architecture, growing period, etc. thus enabling discrimination through remote sensing data.

If there are two crops with similar spectral signatures on a given date (Confection crops), multi-date data may be used to discriminate them. The ratio of near infrared to red radiance is a good indicator of the vigour of the crop. Some of these properties are utilized in crop identification, field forecasting and crop condition assessment (Ayyangar, *et al.*, 1980a, 1980b ; Rao, *et al.*, 1982).

b. Soils

Information on soils is a pre-requisite to agricultural planning. It is a three dimensional quantity and requires soil profile studies at many places. Satellite data helps in reducing the number of profile studies, optimizing their location and also in delineating soil association boundaries.

High resolution stereo data are found useful for generating information on soil resources of 1:12,500 scale necessary for micro-level optimal land use planning. Furthermore, derivative information, such as land capability, land irrigability, erodibility, reclaimability and suitability for different crops which in turn enable preparing the optimal land use plan and in taking up land reclamation measures, whatever required. Models for soil moisture estimation using single frequency, polarization and look angle SAR data, were also developed (NRSA, 1997 ; Rao, *et al.*, 1998).

c. Land use/Land cover

Space borne multispectral data were used to generate district wise land use/land cover maps for the entire country on 1:250,000 scale. Three season data were used to delineate double cropped areas, *rabi*, fallow, etc. (NRSA, 1995).

Regional level mapping of land use/land cover was carried out using WiFS data. With the LISS-III data from IRS-1C and IRS 1D land use/land cover maps at 1:25,000 scale could be delineated and changes therein over a period of time could be monitored using multi-temporal data (Rao *et al.*, 1996 ; NRSA,1997). By merging LISS-III and PAN data digitally, soil resources and land use/land cover maps upto 1:12,500 scale could be generated (Rao, 1999).

d. Floods / Cyclones

Satellite remote sensing is a powerful tool to prepare a flood inundation maps in near real time that can be effectively used for damage assessment and relief management, post-flood river configuration to assess vulnerability of flood control structures, preliminary flood hazard risk zone mapping and flood forecasting are generated using currently available satellite data (Venkatachary *et al.*, 1999; Navalgund, 2002). Flood maps are prepared currently using WiFS and LISS-III sensor data showing flood inundation areas and are provided to the Departments concerned in states and to the Department of Agriculture and Co-operation (DAC), Ministry of Agriculture, Government of India. This activity has been carried out since 1987 under the "Near-Real-Time Flood Monitoring" project sponsored by the DAC.

One of the most important applications of space technology to natural disaster management in the country has been monitoring and landform prediction of cyclones using INSAT AVHRR data. Indian Meteorological Department (IMD) is executing this task operationally (Venkatachary, *et al*, 1999).

e. Water resources

Information on the in-season water availability both surface and sub-surface, during crop season has important bearing on the agricultural operations in an area. By using multi-spectral data, extent of surface water bodies/reservoirs can be mapped and monitored. Multi-date satellite images can be used to update area capacity curves of reservoirs to facilitate computing storage capacity. For tapping sub-surface water, hydro-geomorphological maps showing groundwater prospect areas on as large as 1:25,000 scale can be prepared using IRS-1D images.

Periodic monitoring of command areas using satellite data would help in evaluating the performance of major irrigation systems leading to the initiation of correlative measures.

f. Watershed development

Watershed has been accepted as the basic hydrologic unit to be considered for all developmental programmes. Watershed development requires delineation, characterization, prioritization, generating development plans, monitoring and impact assessment. Space borne remote sensing data are playing an increasingly important role in each of these activities.

While availability of stereo data helps in delineation of micro watersheds, higher spatial resolution data facilities characterization of micro watersheds in terms of their current land use/land cover, physiography, drainage, soil associations, ground water prospects, etc.

Such information conjunctively with other demographic and socio-economic data in GIS environment can be used for prioritization and drawing up locale-specific action plans. Satellite data can be effectively used to monitor changes in vegetation cover, its vigour, spread of surface water bodies, etc. which are some indicators of positive impact. The availability of higher resolution data provides ample scope to monitor the activities at farm level with frequent intervals for tracking, implementation, apply mid-course corrections and assessing effectiveness of implementation (Navalgund, 2002).

The Fig.3.2 shows the various applications of remote sensing in agriculture.

3.1.3 Spectral reflectance of vegetation, soil and water

Typical spectral reflectance curves for three basic features i.e. vegetation, soil and water are shown in Fig. 3.3. These lines represent average reflectance values for the above features.

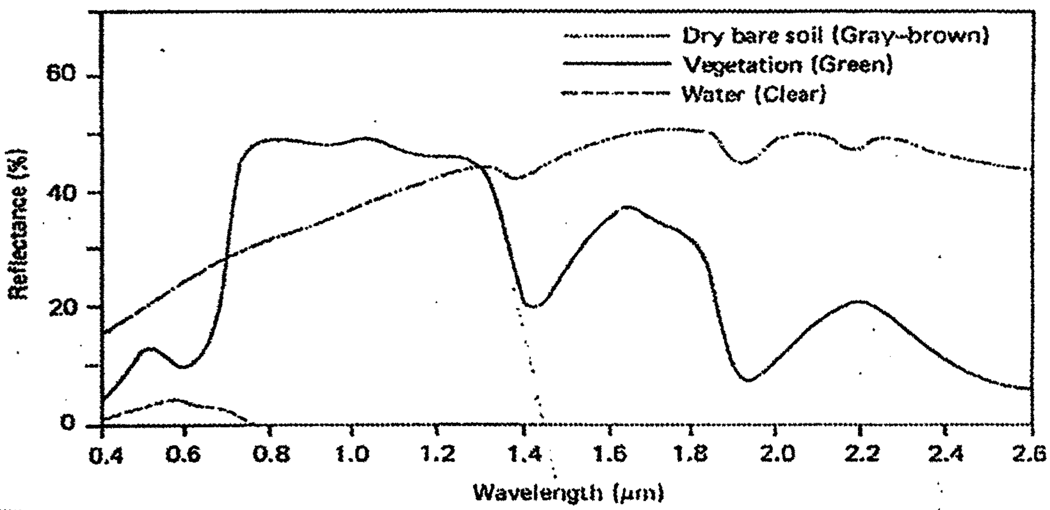
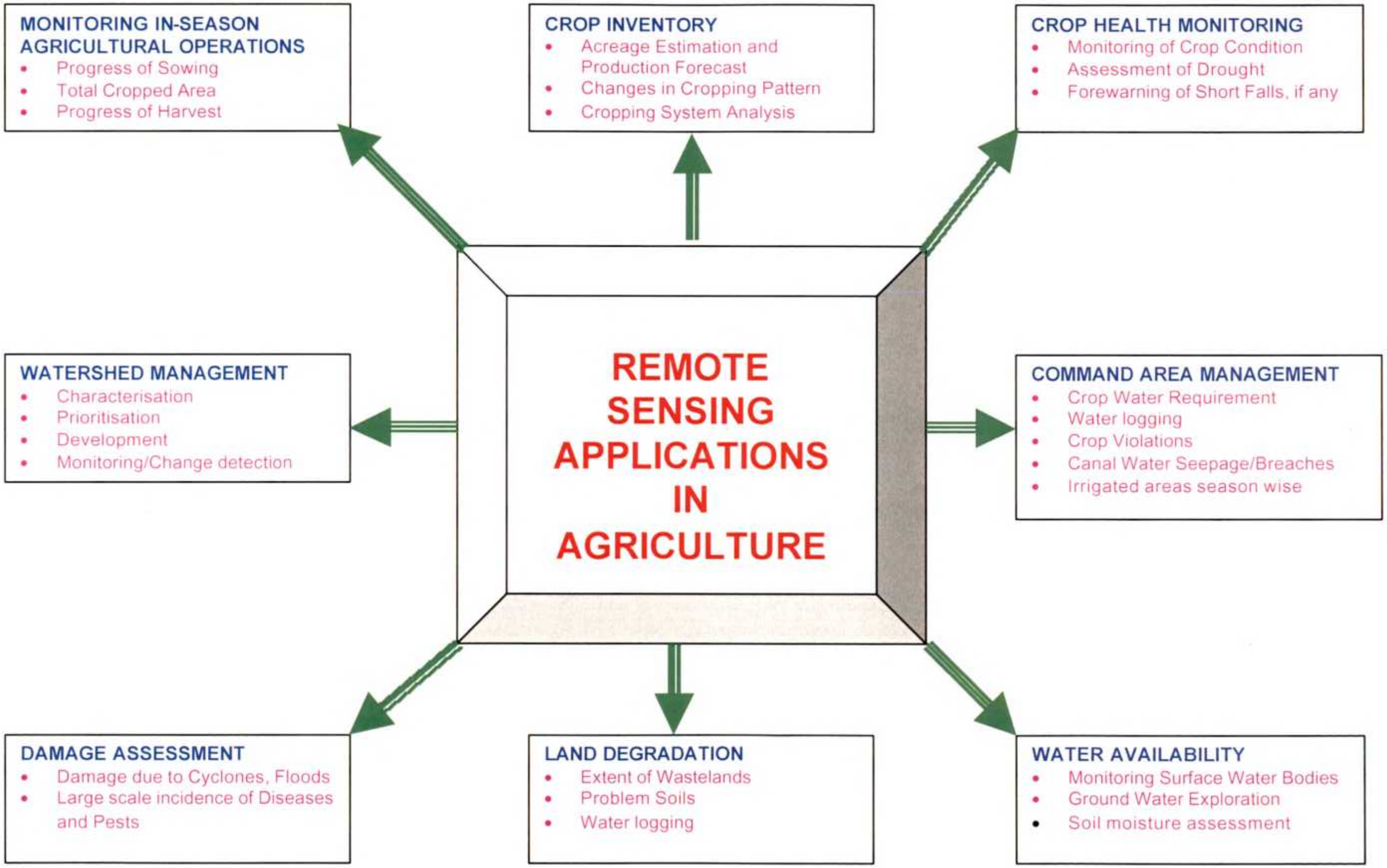


Fig. 3.3: Typical spectral reflectance curves for vegetation, soil and water

(Lillesand and Kiefer, 2000)

Fig 3.2: APPLICATIONS OF REMOTE SENSING IN AGRICULTURE



Spectral reflectance curves for healthy green vegetation almost always manifest the "peak-and-valley" configuration. The valleys in the visible portion of the spectrum are dictated by the pigments in plant leaves. Chlorophyll strongly absorbs energy in the wavelength bands centred at 0.45 and 0.67 μm. The reflectance of healthy vegetation increases dramatically from visible to the Near Infrared (NIR) portion of the spectrum. In the range from 0.7 to 1.3 μm, a plant leaf typically reflects 40 to 50% of the energy incident upon it. Many plant stresses alter the reflectance in this region and sensors operating in this range are often used for vegetation stress detection.

Beyond 1.3 μm, energy incident upon vegetation is essentially observed or reflected with little to no transmittance. Dips in reflectance occur at 1.4, 1.9 and 2.7 μm because water in the leaf absorbs strongly in these wavelengths. So the wavelengths in these spectral regions are referred to as water absorption bands. Reflectance peaks occur at about 1.6 and 2.2 μm, between the absorption bands.

The soil curve shows considerably less peak-and-valley variation in reflectance. That is, the factors that influence soil reflectance act over less specific spectral bands. Some of the factors affecting soil reflectance are moisture content, soil texture, surface roughness, presence of iron oxide and organic matter content. The presence of moisture in soil will decrease its reflectance. In the absence of moisture, coarse-textured soils will appear darker than fine-textured soils. Surface roughness and presence of organic matter also reduce the soil reflectance. The presence of iron oxide in a soil will significantly decrease reflectance.

Absorption of energy at NIR wavelengths and beyond by water is the most distinct characteristic. Locating and delineating water bodies with remote sensing data are done most easily in NIR wavelengths because of this absorption property.

Clear water absorbs relatively little energy having wavelengths less than 0.4 μm. However, as the turbidity of water changes, reflectance changes dramatically. Presence of chlorophyll in water changes its reflectance. Increase in chlorophyll concentration tends to decrease water reflectance in blue wavelengths and increases it in green wavelengths. Thus, the material suspended in the water or with the bottom of the water body alters the reflectance of water (Lillesand and Kiefer, 2000).

3.1.4 Indian Remote Sensing System (IRS)

IRS system commissioned in 1988, has the world's largest constellation of five remote sensing satellites – IRS-1B, IRS-1C, IRS-1D, IRS-P3 and IRS-P4 (OCEANSAT-1) offering space based data in a range of spectral bands, spatial resolutions and swaths. The data is used for several applications covering agriculture, land and water resources, urban development, mineral prospecting, environment, forestry, drought and flood forecasting and ocean resources. Integrated Mission for Sustainable Development (IMSD) is a major mission undertaken in India using space-borne data along with collateral socio-economic data. A Technology Experiment Satellite (TES) has also been launched to test advanced system for remote sensing at high spatial resolution.

Table 1.1 shows the various IRS satellite, payloads and other details.

Table 3.1 : IRS SATELLITES

MISSION	DATE OF LAUNCH	SENSOR	SPECTRAL BANDS (In micrometer)	SPETIAL RESOLUTION (In meter)	SWATH (km)	REPETIVITY (Days)
IRS-1A IRS-1B	March 17, 1988 August 29, 1991	LISS-I	0.45-0.52,0.52-0.59 0.62-0.68,0.77-0.86	72.5	148	22
		LISS-II	0.45-0.52,0.52-0.59 0.62-0.68,0.77-0.86	36.25	2X74	22
IRS-P2	October 15, 1994	LISS-II	0.45-0.52, 0.52-0.59 0.62-0.68,0.77-0.86	37 x 32	131	
IRS-1C	December 28, 1995	LISS-III	0.52-0.59, 0.62-0.68 0.77-0.86,1.55-1.70	23 (VNIR) 70 (MIR)	140 804	24 5
		WiFS	0.62-0.68,0.77-0.86	188	70	5
		PAN steerable±26°	0.50-0.75	5.8		
IRS-P3	March 21, 1996	WiFS	0.62-0.68,0.77-0.86 1.55-1.70	188	810	5
		MOS-A	0.7567, 0.7606 0.7635, 0.7664	1569 x 1395	195	24
		MOS-B	0.408, 0.443, 0.485 0.520, 0.570, 0.615 0.650, 0.685, 0.750 0.815, 0.870, 0.910 0.945	523 x 523	200	24
		MOS-C	1.600	523 x 644	192	24
IRS-1D	September 9, 1997	LISS-III	0.52-0.59, 0.62-0.68 0.77-0.86,1.55-1.70	23 (VNIR) 70 (MIR)	140 804	24 5
		WiFS	0.62-0.68,0.77-0.86	188	70	5
		PAN steerable±26°	0.50-0.75	5.8		

3.1.5 Geographic Information System (GIS)

Remote sensing systems were used to collect a significant amount of spatial data that is turned into information. The spatial data is generally in the form of maps which could be soil types, geology, land cover, water availability etc. Effective utilization of these large spatial data volume is dependent upon the existence of an efficient, geographic handling and processing system. Planning and execution now requires more accurate, reliable and timely information and better tool for the management of such spatial data and non-spatial data. GIS can deal with virtually any type of information about features that can be referenced by geographical location. These systems are capable of handling both location data and attitude data about such features.

A commonly accepted definition of a GIS is "a system of hardware, software, data, people, organization and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth" (Dueker and Kjerne, 1989). The GIS not only permits the automated mapping or display of the location of features, but also provides a capability for recording and analyzing descriptive characteristics about the features.

In resources management, the term spatial data is that which has physical dimensions and geographic location on the ground. Non-spatial data (attribute) consists of textural description on properties which may be associated with graphical entities, for example owners name and address, land use, category, its elevation and vegetative characteristics.

3.1.6 Components of GIS

Any GIS comprises three major components, viz., computer hardware, application software and a proper organizational context. Following sections briefly describe these components.

3.1.6.1 Computer hardware and software

The hardware components include several specialized peripherals, such as digitizer scanner for converting the resource maps into digital form for storage in the computer, a plotter for graphical representation of the maps generated, and a visual colour graphics display unit (work-station) on which the spatial data editing and display can be performed by the user, in addition to a central processing unit, and standard computer peripherals.

The software components are primarily designed to perform five major functions:

a. Data input
b. Data storage and data base management
c. Data processing
d. Data analysis and modelling and
e. Data presentation/output.

a. Data input

An important source of geographically referenced data in the spatial form, collected by aerial photography and satellite imagery are presented in the form of photographs or digital images. Data sources also include paper maps and digital data from other sources. Another source of geographic information is the non-spatial data, such as soil properties, vegetation types, weather station observation, customer lists, water samples, socio-economic survey data, etc. These data bases are often geographically referenced. It is possible to transform and integrate this information into thematic data which can then be processed in the GIS.

Data input involves the conversion of data from the above mentioned different sources, both spatial and non-spatial into compatible digital form, and linking the two. There are various ways to accomplish this depending on the requirements for accuracy and consistency. One way of achieving this is by using manual digitizers wherein the operators follows the lines carefully using the cursor pad, and ensuring that lines are not double digitized and intersections are carefully closed. This mode of entry is tedious, time consuming and operator dependent. The automated digitizing systems, such as scanners replace the manual work of following the lines and thus ensure consistent, repeatable results, each time the map is scanned. Scanners, though expensive, are very effective in high volume applications but limited to only good quality maps.

b. Data storage and data base management

The data storage and data base management are the functions of the data management system of the GIS. They are concerned with the way the data is structured, handled, accessed and perceived by the user of the system. Effective data management includes all aspects related to data security, data integrity, data filing and accessibility, and data maintenance abilities. Data security ensures security against modification of GIS or access of data to unauthorized users. Data integrity defines the ability of the system to protect data from accidental loss or from contamination by extraneous data. Filling and accessibility provides an authorized user to organize the data into categories, directories, study area, etc. Data maintenance provides the authorized users with the ability to update, delete or add data to the GIS database.

c. Data processing

Data processing operations are those performed on the data to produce information. It includes removal of errors and updating or matching them to other data. Errors can arise during the encoding and inputting of spatial and non-spatial data which can be either incomplete or double, in the wrong place, at the wrong scale, distorted or linked to the wrong non-spatial data. Besides, data may be over refined and may need to be reduced in volume. Data editing is interactively performed to ensure that all the errors are corrected, data updated and property verified to achieve the required accuracy, which are vital to analysis.

d. Data analysis and modelling

Data conversion is only part of the input phase of GIS. What is required next is the ability to interpret and to analyze, quantitatively and qualitatively, the information that has been collected. Spatial analysis tools are used to model, made predictions, and reach conclusions about the problems or interest. Such analysis involves combining data from multiple spatial data categories and performing analytical statistical measurements, and other operations on the GIS data sets to transform the data into information suitable for a given application. Typical operations include overlaying different thematic maps, computing areas, performing proximity searches, buffer zone creations, performing logical operations, scale changing, etc. Other techniques are creation of three dimensional perspective view using elevation data and generation of slope maps, network analysis, costing etc. Some of these are briefly described in the following paragraphs.

i. Overlay: Features from different layers can be combined to form a new map by overlaying the layers. Selective overlay of polygons, lines and points enables the users to generate a map containing features and attributes of interest, extracted from different themes or layers.

ii. Buffer generation: One important class of spatial operations concerns the determination of areas and features which fall within a specified distance of interest by generating buffer zones. Such buffer zones can be generated around points, lines or polygons. These zones are always polygons which are created as a separate layer. Distance buffering enables specifying different buffer distances for features based on feature attributes.

iii. Clipping: Provides means of extracting a given area of interest for analysis from the geographic database.

iv. Proximity search: Proximity analysis enables to derive the spatial suitability based on neighborhood analysis techniques. It presents various options, such as user defined locations to point features, line features, polygons etc.

v. Modelling: As it is possible to analyse spatial information to extract knowledge, it is also possible to use known relationships to model geographically the outcome of a set of conditions. In other words, a GIS model is to determine the best solution for a given problem based on a set of criteria. The relationships in modelling are expressed within the GIS as algorithms or mathematical formulae which perform the calculations required by the models.

e. Data presentation/output

Data presentation deals with the way the information is displayed to the user. It can be either a visual display or hard copy in the form of printed maps drawn using a plotter.

3.1.7 ARC/INFO GIS software package

There are many GIS software packages available in the market. SPANS, URAS/MASMPA, PAMAP GIS, GISNIC, MAPS/PC-MAPS, ISROGIS, INGIS, MAPINFO, ARC/INFO. Some are vector based, some are raster based and some are hybrid type.

The INGIS package was developed at the Regional Remote Sensing Service Centre (RRSSC), Bangalore on the VAX 11/780 platform and operationalised at all the RRSSCs. This package has been subsequently ported into the PC platform and operationalised as : PC-INGIS under MS-DOS and GEOSPACE under XENIX operating systems. The ISROGIS package was developed by the Space Applications Centre (SAC) which work under UNIX environment on PC platforms.

At present the hybrid GIS packages which handle both raster and vector data are more popular. ARC/INFO is one of the popular hybrid types of GIS package.

ARC/INFO is a cartographic system built around a hybrid data model. It organizes geographic data using a relational and topological model which provides the efficient handling of both spatial and attribute data. It provides all the five major functions of GIS, i.e., data input, data storage and data base management, data processing, data analysis and modelling, data presentation/output.

In ARC/INFO ARC handles where the features are, while the INFO component handles the feature descriptions and how each feature is related to other.

ARC is the main programme environment in ARC/INFO. It includes command such as data conversion/coding, map digitization and editing, error check and verification, management and manipulation of feature attribute, analytical operation like map overlay, buffer generation, proximity analysis, generation of statistics, etc. in short all general GIS functions are done by ARC level commands. INFO, ARCREDIT, ARCPLOT, TIN, ROUTE, ALLOCATE, ADS, COGO, GENERATE are the sub- environment of the ARC module.

a. INFO

A tabular data base management information system used by ARC/INFO to store, manipulate and display feature attribute and related tables associated with geographic features maintained by ARC.

b. ARC EDIT

It is the main tool for data processing. It is a Complete Sub- system and has its own set of commands.

- Creates new coverages (Simply/match to 'background' coverages)
- Edits the existing coverages
- Updates the existing coverages and
- Handles features and attributes.

c. ARC PLOT

It is the graphic display subsystem. It has a set of commands (Tools). Each command has a specific purpose. Sometimes commands can be combined to produce required devices results.

Capabilities

- Drawing coverage features
- Coverage error detection
- Multiple coverage input
- Map generation
- Map scaling, rotation and positioning
- Map symbol/definition
- User defined/attribute controlled symbolism
- Key and legend generation
- Data extraction from map library
- Line generalization during display and
- Queries for contents of a coverage or map library

d. TIN

This ARC/INFO software product is used for surface representations, modelling and display. It can be used with any continuous spatial distributed data like elevation, water table, geologic strata, land value trends, population distribution, air pollution, concentrations, average rainfall etc.

e. ADS

This is Arc Digitizing System. A very simple digitizing and editing system used to add ARCS and lable points to a coverage.

f. COGO

This is the name of the Coordinate Geometry software product for ARC/INFO. COGO functions are used to enter survey data into an ARC/INFO coverage, to calculate precise locations and boundaries to define curves and so on.

g. GENERATE

It is used to convert ASC II text file data into ARC/INFO coverage. GENERATE has its own prompt and its own set of sub commands.

h. ROUTE AND ALLCOATE

These are subsystems for dealing with networks.

i. AML (Arc Macro Language)

A high level, algorithmic language that provides full programming capabilities and a set of tools for developing menu-drives used interfaces designed to meet the needs of end users. Features include the ability to create on-screen menus from text files, to use and assign variables, and to get and use map or page unit coordinate. AML includes an extensive set of directives and in-line functions that can be used interactively or in AML programmes (macros) as well as functions that report on the status of ARC/INFO command parameters.

3.2 Analysis of Satellite Data for the Study Area

The details of the study area, digitization of watershed boundary, extraction of the study area, analysis of the remote sensing data of two periods and derivation of changes that have taken place are presented in this part.

Satellite remote sensing data of the watershed pertaining to two periods were analysed. The analysis involved geometric corrections, digitization and extraction of the study area, quantification of improvements in the arable and non-arable lands. The classified images were compared to derive information on changes. The parameters, which were derived from satellite data, were considered for monitoring purpose. The methodology flow chart is given in Fig.3.4.

3.3 Salient Features of the Watershed

Peddakalvapalle watershed was selected for the study. Peddakalvapalle watershed is located in Chittoor District, Andhra Pradesh and falls in the Southern zone (Zone-4) of Andhra Pradesh. The watershed is a compact block with a total geographical area of 8,241.39 ha and is situated between 14°00' to 14°10' North latitudes and 78°35' to 78°45' East longitudes. The watershed is located to the West of Rayachoti and covers 43 villages and parts of Madhavaram reserve forests.

The average annual rainfall of the watershed is about 730.04 mm. The rainfall is highly erratic and occurs mainly in the months of June to October. The topography of the watershed is undulating with shallow soils. Surface storage is low and infiltration is also low to normal. The infiltration rate ranges from 6-10 cm/hr.

The soil types of the watershed are sandy loam and red earth and the agricultural crops grown are groundnut, pigeonpea, field beans, sunflower and chickpea.

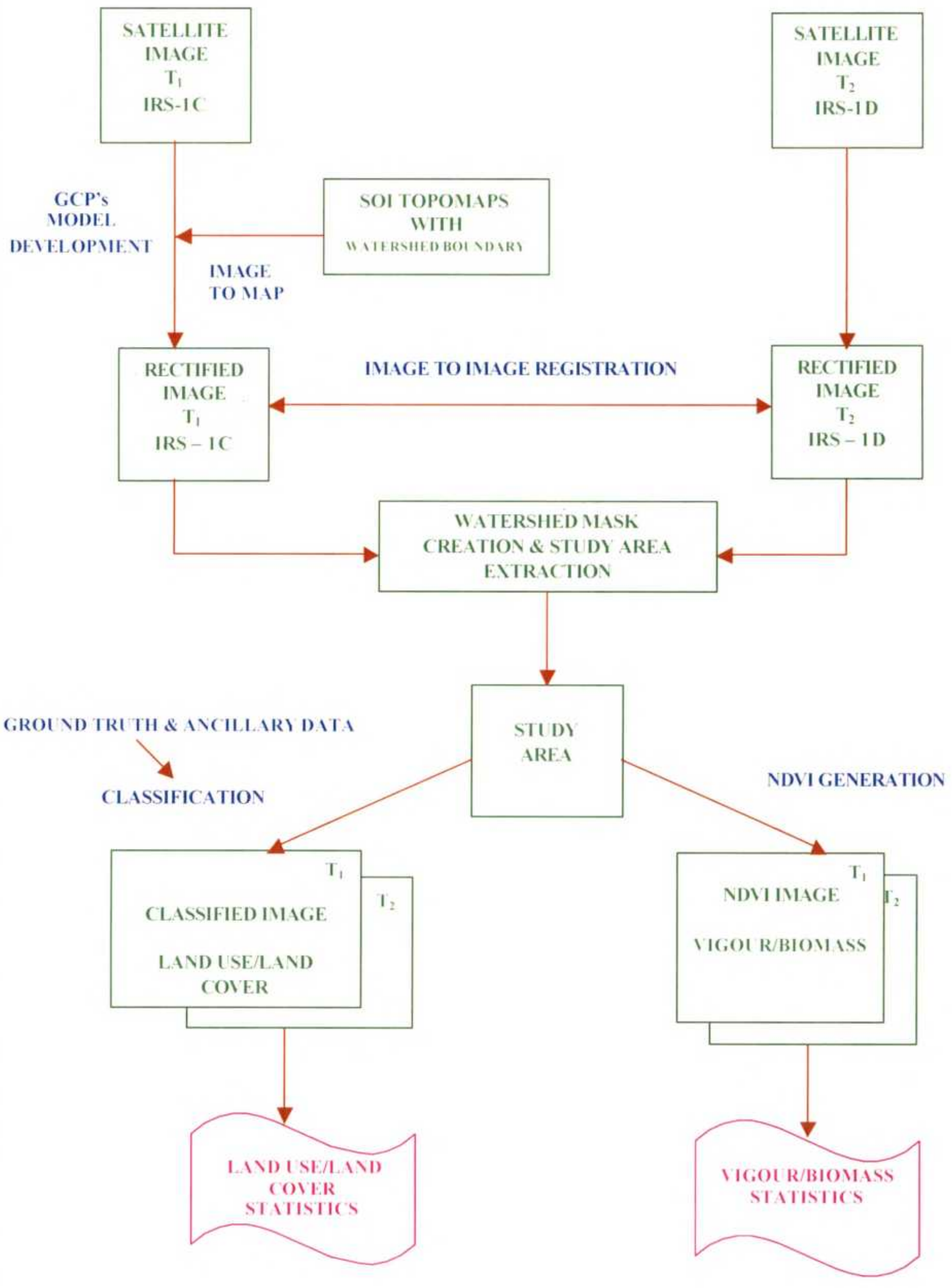


Fig. 3.1: WATERSHED MONITORING METHODOLOGY FLOW CHART

3.4 Data Used

3.4.1 Satellite data

The Indian remote sensing satellite (IRS) data of LISS-III sensor with a spatial resolution of 23.5 m were used for the study. IRS-1C data of February 12, 1997 and IRS-1D data of February 25, 2002 covering the watershed were analysed to assess the changes in biomass and land use/land cover that have occurred over a period of five years. The watershed is covered in satellite path and row of 100 and 63. The satellite data analysis was carried out at the Regional Remote Sensing Service Center (RRSSC-B), ISRO, Bangalore using the state-of-art IBM RS6000 computer system and EASI/PACE software.

3.4.2 Ancillary data

Ancillary data like SOI (Survey of India) map of 1:50,000 scale was procured from SOI office, Hyderabad. The watershed is covered in the Survey of India topomap 57 J/12 on 1:50,000 scale.

3.4.3 Ground truth data

The ground information on different land use/land cover categories was collected by visiting the sample areas in the watershed along with satellite imagery.

3.5 Grid base generation

The regional referencing scheme, i.e., gridbase was generated for the watershed consisting of latitude and longitude of 5 minute interval. The grid base had the characteristics of polyconic projection and with central meridian for a region covering an area of 10°x 10°. The grid base was generated to register the scanned maps with high accuracy and to bring projection properties to the scanned maps.

3.6 Scanning of Maps

The map containing the information of cultural features like roads, railways, administrative boundaries and notified forest boundaries, elevation contours and other related information like stony waste, plantation area, grazing land, pasture land, scrub lands was scanned using AO size raster scanner. While scanning, two important parameters were precisely set, one was DPI (Dots per Inch) and another was threshold. The DPI and threshold were based on drawing characteristics and information required. For this project, a DPI of 100 and threshold of 100 were identified as optimum range of values.

3.7 Registration of Scanned Maps

Using GCP works module of EASI/PACE Environment, the scanned map was registered. The mosaic of the study area was prepared and it was registered to the already generated grid base file.

3.8 Registration of Satellite Data

The task of registration of satellite data consisted of the following activities.

3.8.1 Loading of data

The satellite data of post and pre dates were loaded from CD ROM received from National Data Centre (NDC), National Remote Sensing Agency (NRSA) to disk using ERDAS imagine software of version 8.4.

3.8.2 Georeferencing of IRS LISS-III data

Registration with respect to mapgrid in the scale of 1:50,000 involved generation of image to image transformation model. Registration of satellite data with high accuracy, i.e., mean residual error and standard deviation less than half a pixel (11.75 m approx.) was one of the motives for generating the map grid. The pre-requisite for registration was collection of proper GCPs. Features of almost permanent nature depicted on maps were chosen for this purpose. They were road intersections, confluences of rivers, streams, bridges, etc. GCPs were collected such that they were evenly distributed over the whole area of the scene. Points outside the watershed boundary were given to control geometric distribution of rectified image. With adequate GCPs, a second order model was used to remove all the error including warping effect. On feeding all the possible GCPs were examined for residual errors and those with maximum residual errors were eliminated before second order model was recalculated. The process of calculation of model was repeated till the mean residual error as well as standard deviation of residual error were well below the threshold (i.e., less than half a pixel).

3.9 Head on Digitisation of Cultural Features

The mapgrid facilitates the head on digitisation of cultural features with high geometrical accuracy and aerial extent. The different features on the map were then digitised. The digitisation was done in vector format. The watershed boundary was extracted from the Survey of India Toposheet 57 J/12 and drainage information was digitized in vector format based on the contour information and drainage information available from the topomaps. Unique files were created for different features such as road network and human settlements.

3.10 Classification of Satellite Data

The overall objective of image classification was to automatically categorize all pixels in the image into land use/land cover classes or themes. Images of both the periods were classified using supervised classification technique.

3.10.1 Supervised classification

The supervised classification process comprises of three steps.

- Acquisition of ground truth
- Calculation of statistics of training sets
- Classification using Maximum Likelihood (MXL) algorithm.

3.10.1.1 Acquisition of ground truth

To yield acceptable classification results, training data must be both representative and complete. The training areas were selected for all the classes such that the classification was homogeneous and bordering pixels were not included. Class training statistics was developed for all the spectral classes of the images. The following classes were generated in this process.

a) Irrigated crop
b) *Kharif* season lands
c) Water bodies
d) Open scrub
e) Stony waste
f) Waste lands
g) Forest.

3.10.1.2 Statistics generation

In this process, statistics for different training sets were generated. Reliability test of training sets was calculated by measuring the statistical separation between classes by computing divergence matrix. The overall accuracy of the classification was finally assessed with reference to ground truth reserved for this purpose.

3.10.1.3 Classification

The statistics of the training sets thus obtained were used for classifying the image using Gaussian Maximum Likelihood classifier (MXL). The MXL quantitatively evaluates both the variance and covariance of the category spectral response patterns while classifying an unknown pixel. This algorithm assumes gaussian (normal) distribution and each pixel is considered as a separate entity independent of neighbours. Using multivariate sample mean vector and interband variance co-variance matrix, the probability of every pixel were calculated for each class and the pixels are assigned to that class which has the highest probability. Those pixels not meeting the probability criteria are to be assigned to reject class (Lillesand and Keifer, 2000). Thus by using MXL, all the pixels in the image were classified into different categories.

3.11 Creation of Normalised Difference Vegetation Index (NDVI)

The spectral response of green and healthy vegetation is characterised by strong absorption in the red region together with a high reflection in the (NIR) Near Infrared region of the electromagnetic spectrum. The NDVI is highly correlated with vegetative parameters such as green leaf biomass, leaf area and is an indicator of photosynthetic activity and hence is of considerable value for vegetation discrimination and seasonal monitoring. NDVI has been used to describe vegetation dynamics and monitor the seasonal growing conditions for making primary productivity analysis.

NDVI is computed by using the infrared (IR) and red reflectance data as given below:

$$NDVI = IR - R / IR + R \text{ --------------- } (3.2)$$

The values for NDVI range from +1.0 to -1.0. Vegetated areas generally yield high values of NDVI because of their relatively high NIR reflectance and low visible reflectance. Water, snow and clouds have negative IR radiation. Rocks and bare soil have NDVI values around zero since they have similar reflectances in both the bands and represent areas without any vegetation cover. Only green vegetation has positive NDVI values and high values being associated with higher densities/vigour of any given healthy biomass (Lillesand and Kiefer, 2000., Sabins, 2000).

NDVI maps were generated by using the above equation for the study area for both the periods. The study area was classified into following different biomass levels and area under each class calculated.

a) Very high

b) High

c) Medium

d) Low

e) Very low.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Remote sensing satellites IRS IC/1D orbit the earth at an attitude of 820 km (approx.) and capture the information on earth surface features in green, red and infrared and shortwave infrared bands of the electromagnetic spectrum with repetitive coverage of 5-22 days. The FCC (False Colour Composite) were generated by combining the information in blue, red and green bands. Based on the availability of satellite data and other ancillary information the watershed was taken for monitoring purpose. The watershed boundary was delineated from SOI topomap using drainage and contour information. The satellite images of the watershed in the form of FCC corresponding to February 12,997 and February 25, 2002 were presented in the plates 4.1 and 4.2

The Peddakalvapalle watershed is a compact block with rectangular shape and slightly elongated in East-West direction. The topography of the watershed is undulating and the drainage pattern is dendritic. The watershed drains into the Mandavi river. The soil type is shallow and it is red sandy loam with considerable amount of area under scrub and stony waste. The average rainfall of the watershed was about 730.04 mm. The infiltration rate was low to normal and it range from 6-10 cm/hr. The maximum and minimum contours of the watershed are 960 and 400 m respectively.

The satellite images of both the periods were classified into different land use/land cover categories by supervised classification. Training statistics for all the

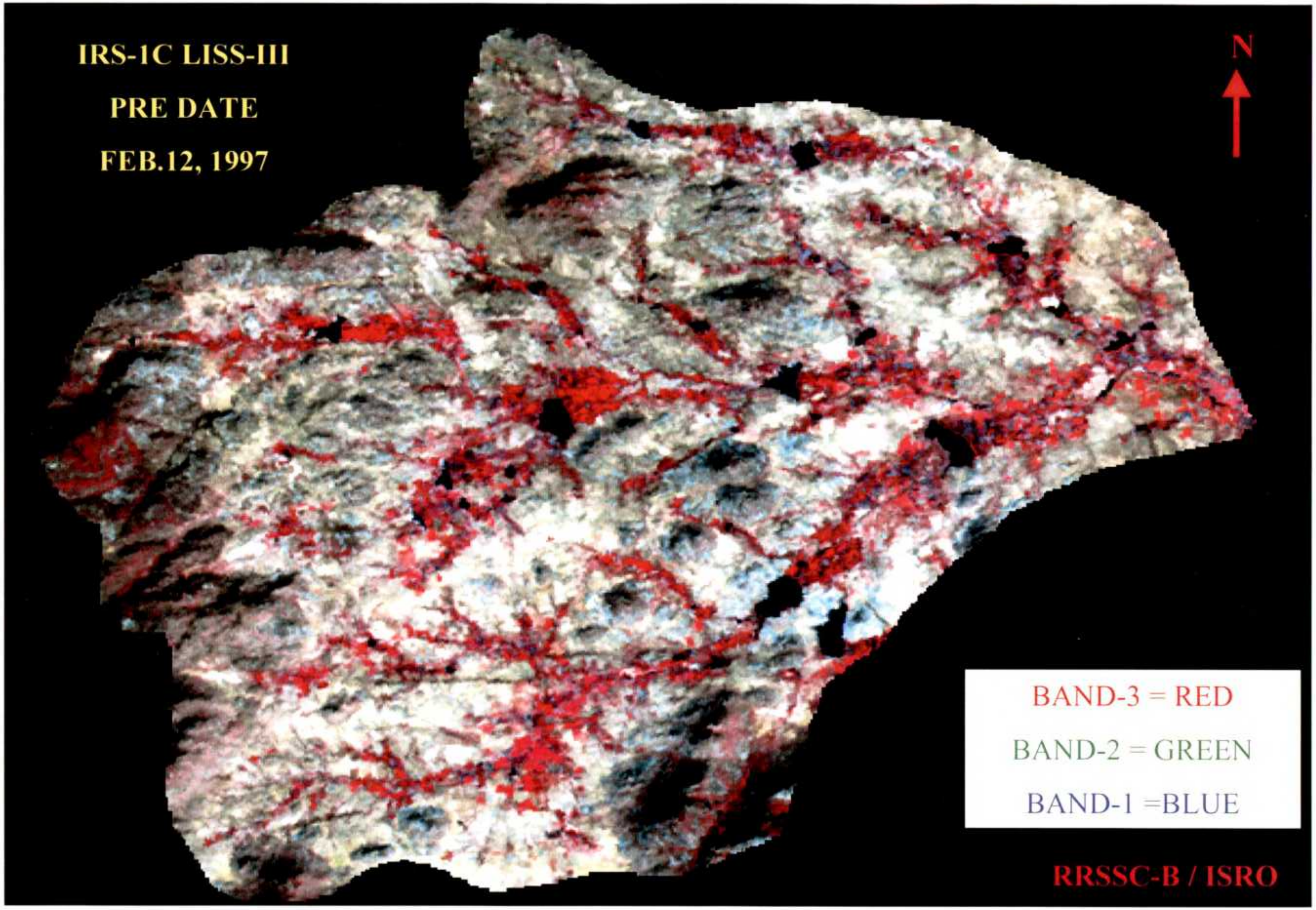


PLATE No.4.1 : FCC OF PEDDAKALVAPALLE WATERSHED CORRESPONDING TO 1997

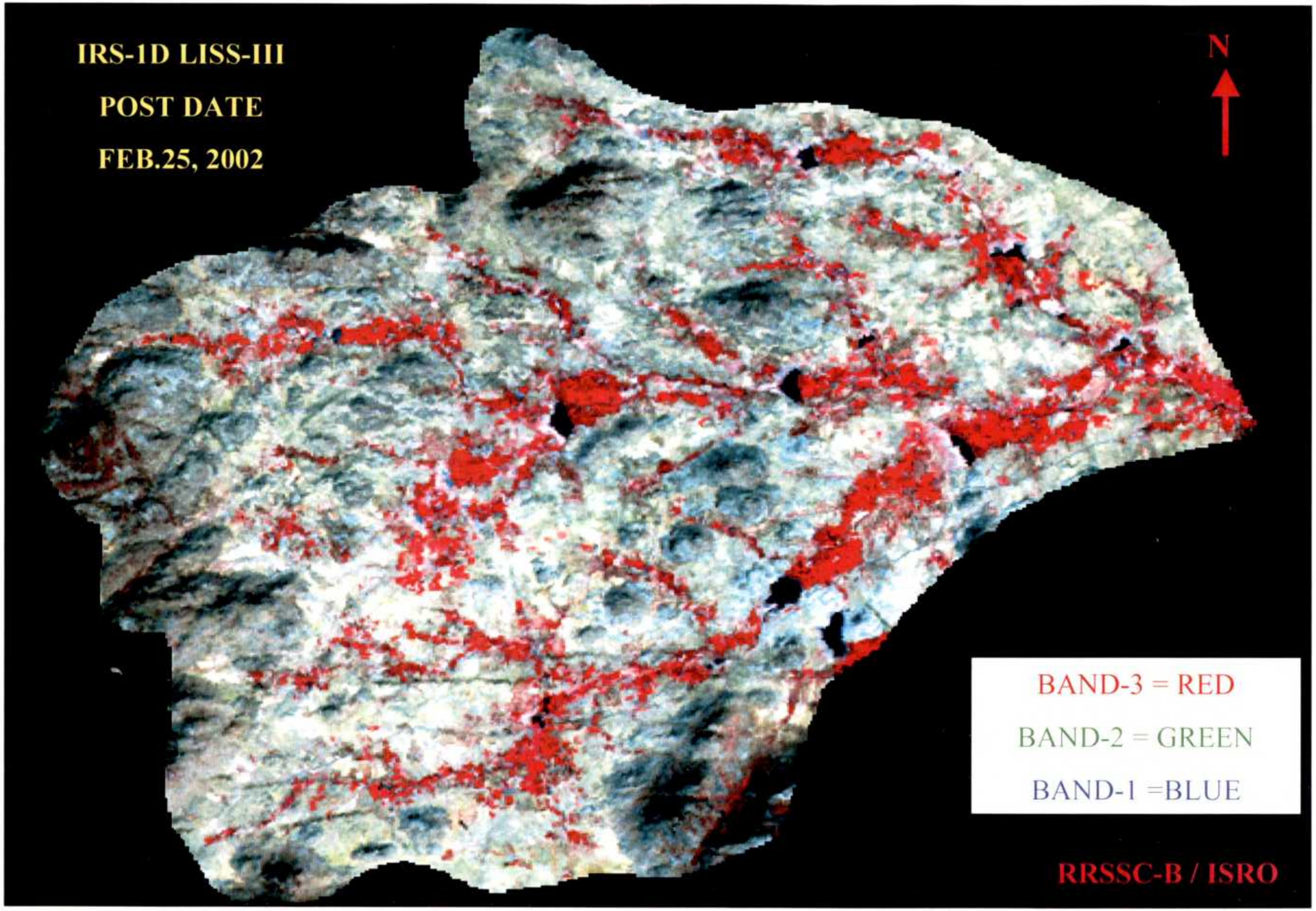


PLATE No.4.2 : FCC OF PEDDAKALVAPALLE WATERSHED CORRESPONDING TO 2002

categories were obtained with limited ground truth information and MXL algorithm was used to classify the pixels into different land use/land cover categories. Spatial distribution of different land/land cover categories during 1997 and 2002 are presented in plates 4.3 and 4.4. During the period from 1997 to 2002, it was observed that the area under irrigated lands and *kharif* season lands increased considerably. Reduction in the area under watershed and scrub was also observed. The Table 4.2 shows the statistics of the area under different land use/land cover categories for both the periods indicating transformation. The Fig. 4.1 shows the area under different land use/land cover classes during 1997 and 2002.

Table 4.1: Areal extent of land use/land cover classes during 1997 and 2002 in Peddakalvppalle watershed

Sl.No.	Land use/ land cover	1997		2002		Changes (±)	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
1	Irrigated crop	2024.16	24.56	2510.64	30.46	+468.48	+5.9
2	*Kharif* season lands	2211.92	26.84	2869.44	34.82	+657.62	+7.98
3	Water bodies	70.47	0.86	88.53	1.07	+18.06	+0.21
4	Open scrub	2061.00	25.01	1543.37	18.73	-517.63	-6.28
5	Stony waste	863.55	10.48	436.33	5.29	-427.22	-5.19
6	Waste lands	134.64	1.63	45.56	0.55	-89.08	-1.08
7	Forest	875.70	10.63	747.53	9.07	-128.23	-1.56

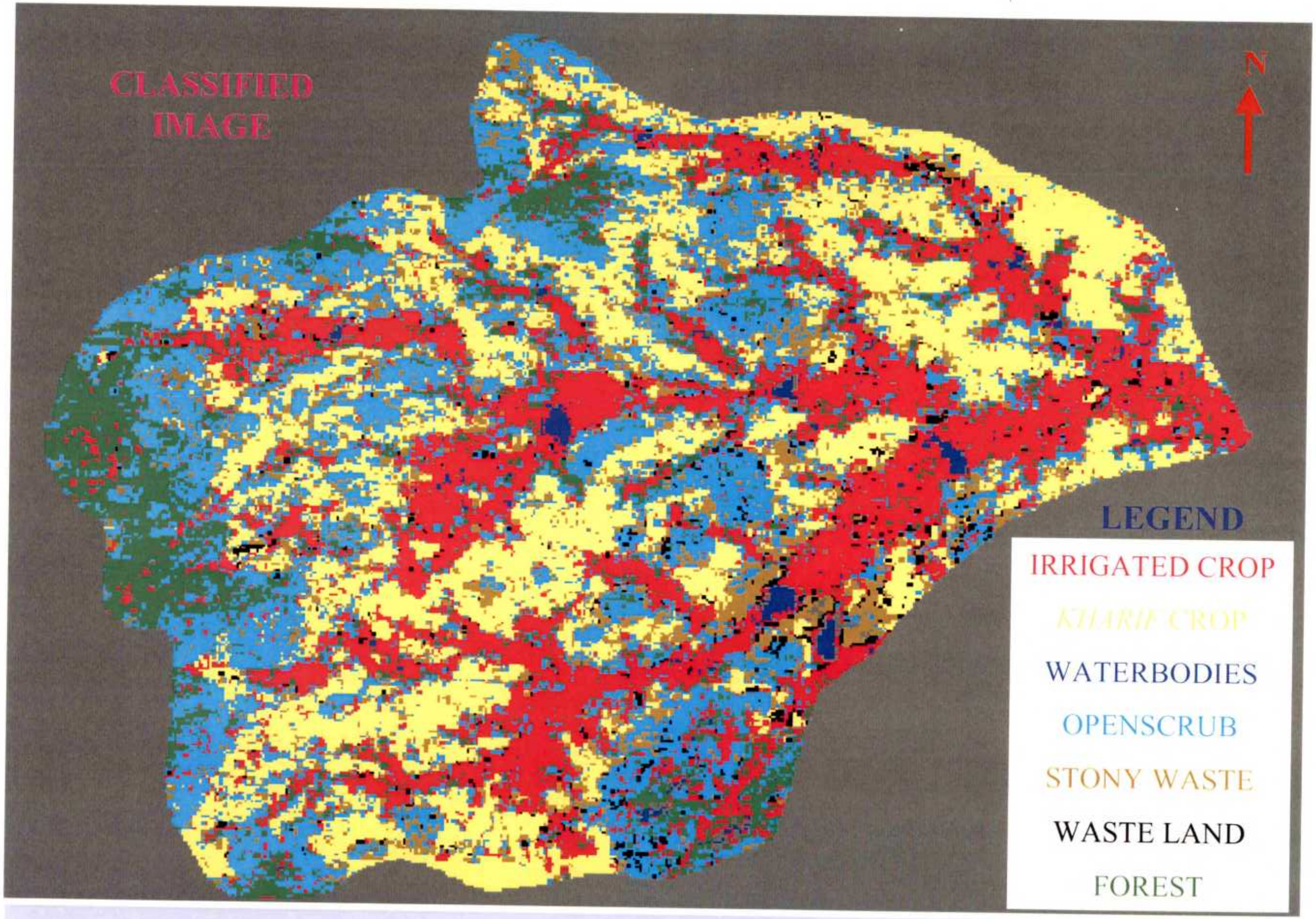


PLATE No.4.3 : SPATIAL DISTRIBUTION OF DIFFERENT LAND USE / LAND COVER CATEGORIES DURING 1997

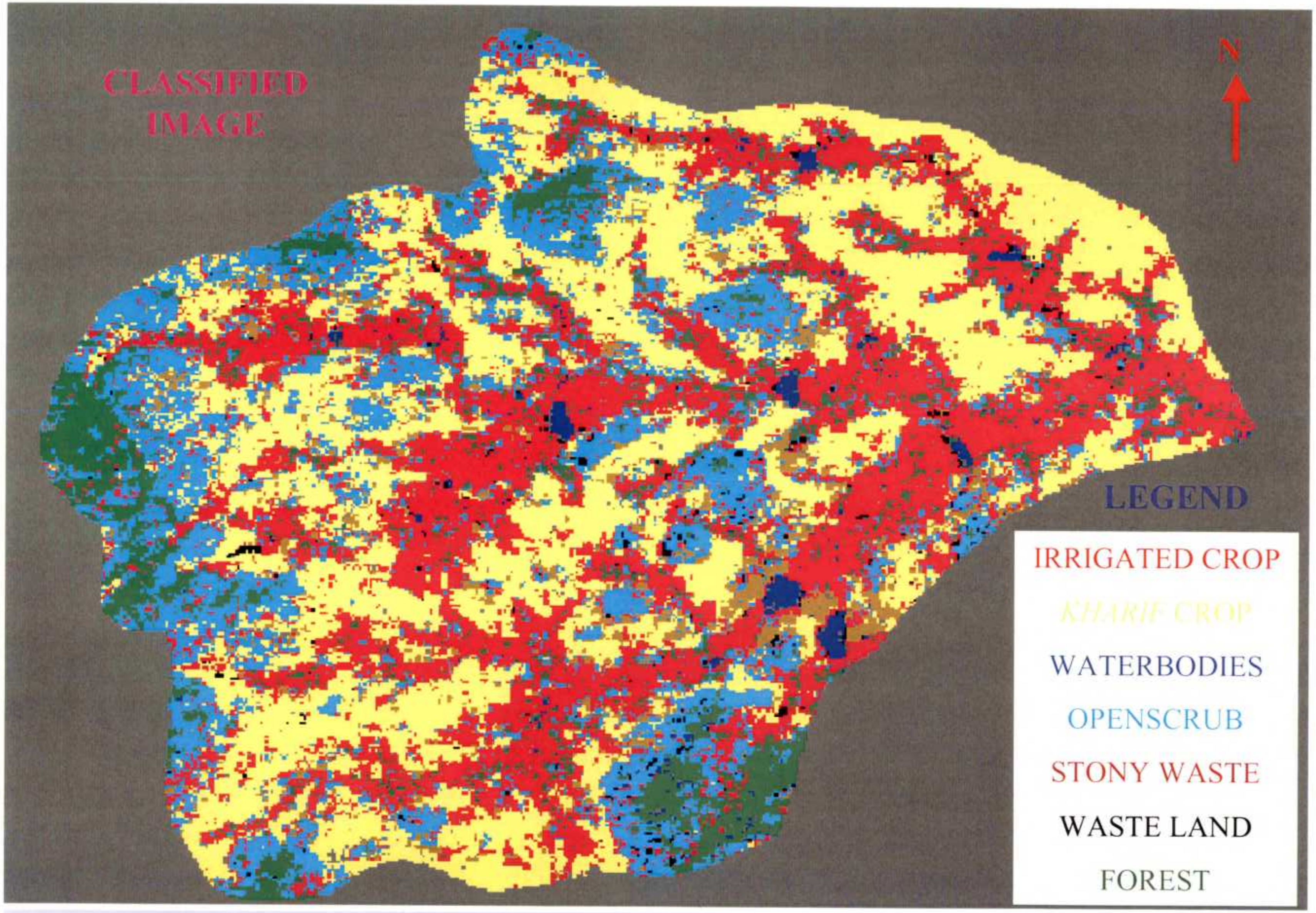


PLATE No.4.4 : SPATIAL DISTRIBUTION OF DIFFERENT LAND USE / LAND COVER CATEGORIES DURING 2002

AREA UNDER DIFFERENT LAND USE / LAND COVER CLASSES DURING 1997 AND 2002

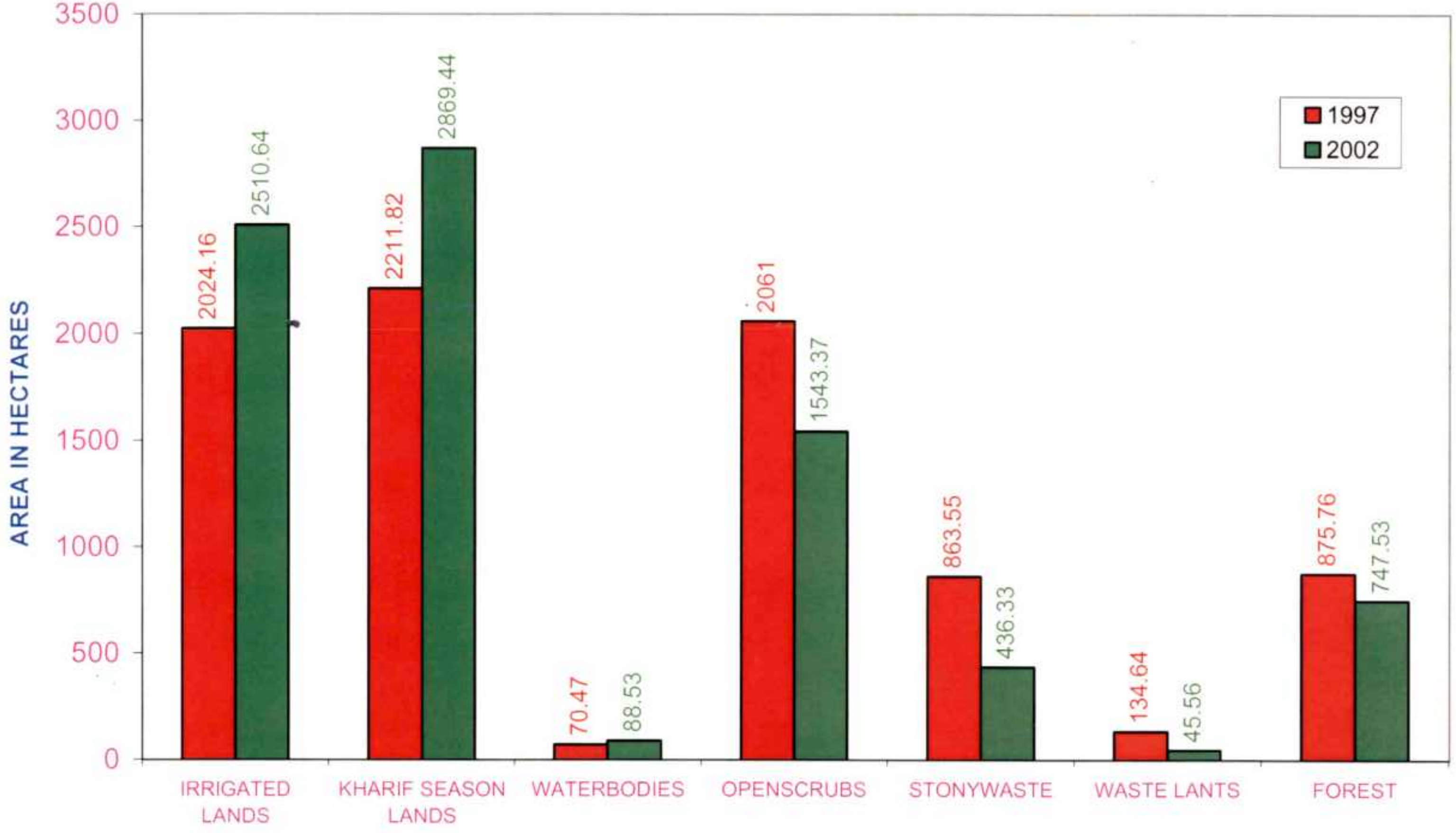


Fig. No. 4.1

From land use/land cover analysis, it was observed that the area under waterbodies increased by 18.06 ha (0.21%) from 1997 to 2002. This may be due to construction of water harvesting structures, practice of soil conservation measures.

The irrigated crop area comprised of the area under irrigated crops and lands under agro-horticultural practices. It was observed that the area under irrigated crop increased significantly. The total area under this category was 2,024.16 ha during 1997 and 2,510.64 ha during 2002 indicating an increase of 486.48 ha (5.9%). This increase in the area may be attributed to better utilization of surface and ground water, changes in cropping pattern, introduction of hybrid crop varieties and horticultural plantations and transformation of marginal lands.

The area under *kharif* season lands increased by 657.62 ha during the study period from 1997 to 2002. This increase may be due to practice of various soil and water conservation measures, better utilization of surface water, conversion of waste lands and scrub lands into fallow lands.

Considerable amount of wastelands were transformed to fallow lands during the study period from1997 to 2002. The area under wastelands decreased by 89.08 ha (1.08%). These wastelands were reclaimed for productive use by adopting suitable treatment measures like better soil and water conservation practices.

Significant reduction in the area under scrub and forest was observed from 1997 to 2002. The area under scrubs and forests decreased by 517.63 ha (6.28%) has and 128.23 ha (1.56%). These changes were due to conversion of scrubs and forests into fallow lands and cropped areas. NDVI maps were generated for the study area by rationing infrared and red bands for both the periods based on ground truth. Spatial distribution of different biomass levels in the watershed during 1997 and 2002 are presented in plates 4.5 and 4.6. From both the images, it was observed that the vegetation increased considerably during the period from 1997 to 2002. The increase may be due to adoption of soil and water conservation practices, better utilization of surface and ground water, changes in cropping pattern, introduction of hybrid varieties, use of fertilizers, etc.

The Table 4.2 shows the statistics of the study area under different biomass levels during the period 1997 and 2002 indicating transformation. Fig. 4.2 shows the area under different biomass levels during 1997 and 2002. Significant increase in the area under high and medium biomass levels was observed during the study period. The area under very high, high and medium biomass levels increased by 244.98 ha (2.97%), 319.92 ha (3.88%) and 552.14 ha (6.7%), respectively. These changes may be due to the better utilization of surface and groundwater, practice of soil and water conservation measures, changes in cropping pattern, use of fertilizers and pesticides, introduction of hybrid varieties and horticultural plantations. The area under low biomass levels decreased by 1120.13 ha (13.59%).

Benefit – Cost Analysis of Remote Sensing and GIS

An exercise was done to bring out the benefits and costs of using remote sensing and GIS to monitor the land use and biomass changes in a watershed over the conventional / manual methods. The cost of each IRS LISS – III image covering an area of 141 km x 141 km was Rs.16000/- and it needed another Rs.14000/- for processing. Thus to total cost of monitoring land use and biomass worked out to Rs.30000/- per imagery and the cost per ha come to Rs.0.0315 only for each season.

But, considering the present Peddakalvapalle watershed whose geographical area was only 8241.39 ha out of the imagery of 1988100 ha (141 km x 141 km), the cost of monitoring of land use and biomass changes worked out to Rs.7.30/ha by processing the two imageries got on 12.02.1997 and 25.02.2002. The same work, if done manually by engaging surveyors would amount to Rs.16.00/ ha assuming a team of 2 persons covering an area of 50 ha per day with wages at Rs.200 per person per day. Thus the use of remote sensing and GIS was cheaper by 2.2 times than that of conventional methods. But, one great advantage was that no manual surveying could be done for the past period and it is possible only through remote sensing and GIS by processing the imageries of past periods. Another, advantage was the time required for conducting monitoring. The manual or conventional methods need 328 man-days where as the same work could be done in 30 man-days and this is really greatest advantage among all.

Table 4.2: Area extent of different biomass levels in the watershed during 1997 and 2002

Sl.No.	Biomass levels	1997		2002		Changes (±)	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
1	Very high	372.99	4.53	617.97	7.50	+244.98	+2.97
2	High	876.03	10.63	1195.95	14.51	+319.92	+3.88
3	Medium	4656.13	56.50	5208.27	63.20	+552.14	+6.7
4	Low	2281.95	27.69	1161.82	14.10	-1120.13	-13.59
5	Very low	54.29	0.66	57.38	0.70	+3.09	+0.04

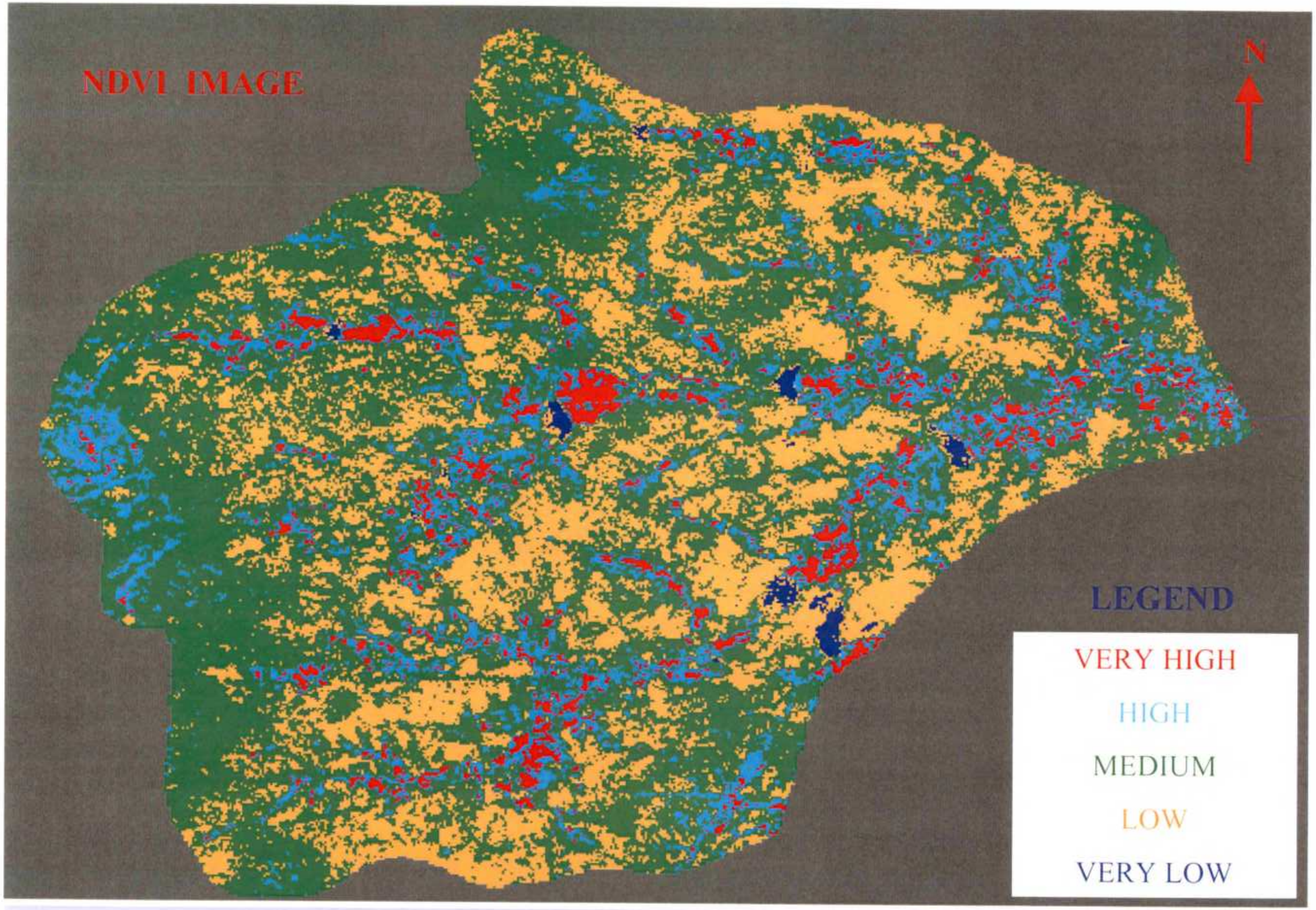


PLATE No.4.5 : SPATIAL DISTRIBUTION OF DIFFERENT BIOMASS LEVELS DURING 1997

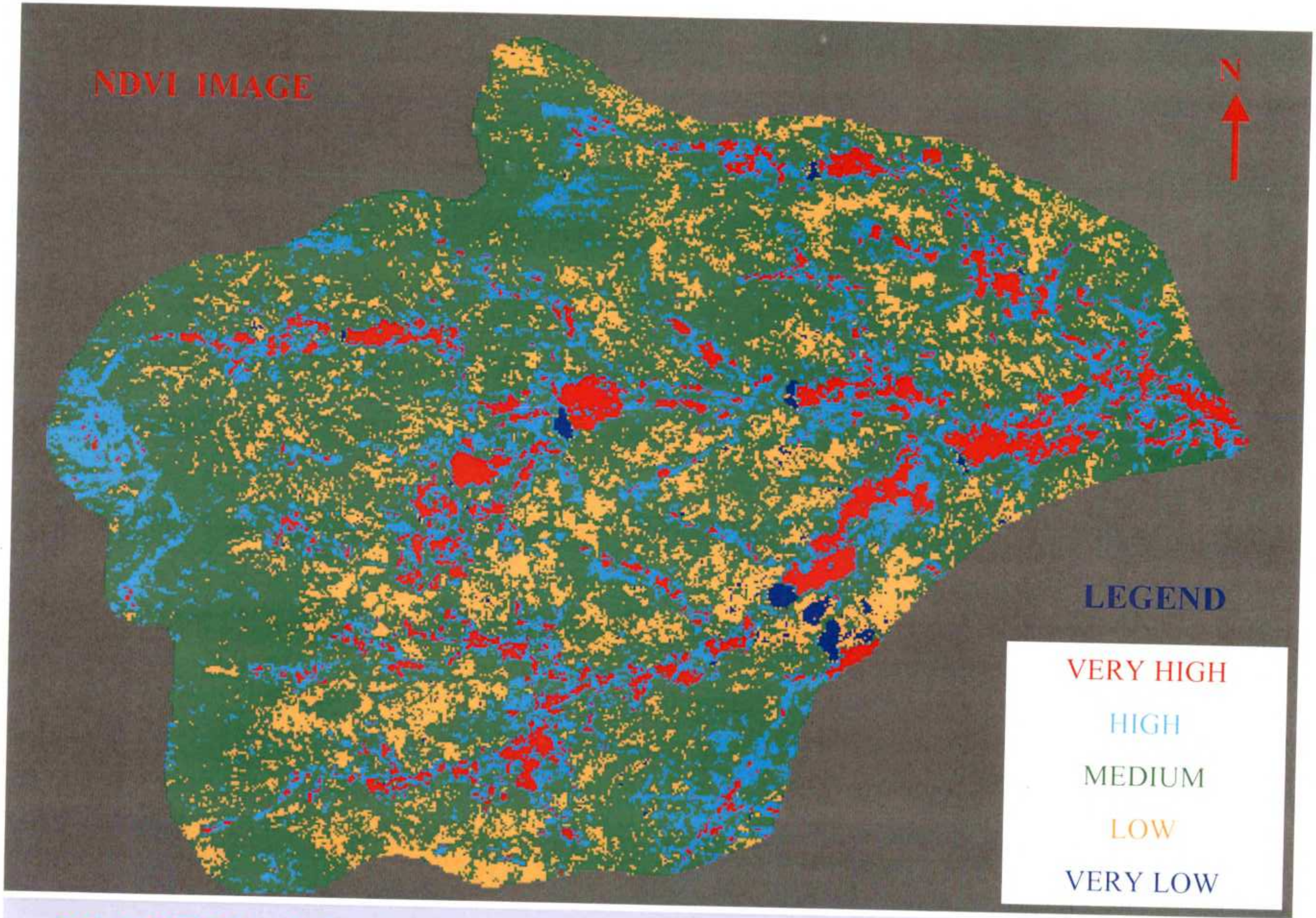


PLATE No.4.6 : SPATIAL DISTRIBUTION OF DIFFERENT BIOMASS LEVELS DURING 2002

AREA UNDER DIFFERENT BIOMASS LEVELS DURING 1997 AND 2002

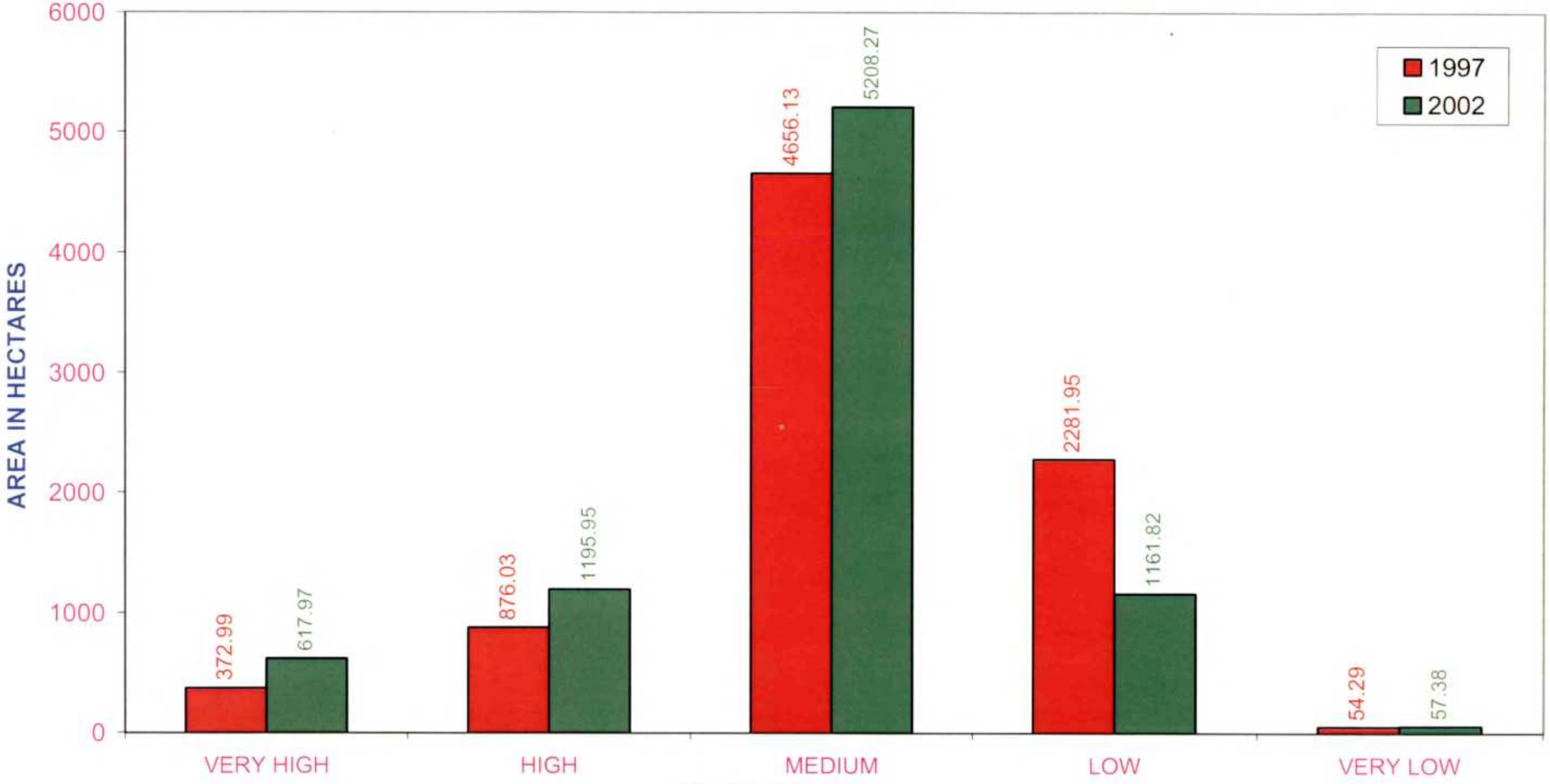


Fig.No.4.2

SUMMARY AND CONCLUSIONS

CHAPTER-V

SUMMARY AND CONCLUSIONS

Information on changes in natural resources in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental studies, economic production etc. (Anonymous, 1989). Conventional ground survey methods of land use mapping are labour intensive, time consuming and are done relatively infrequently. These maps soon become outdated with passing of time, particularly in a rapidly changing environment. In recent years, the remote sensing techniques have proved to be rapid, cost effective and provides timely information with the capability of repetitive coverage of a given area/zone once in 5 to 22 days.

The repetitive coverage of the satellite provides us an excellent opportunity to monitor the land resources and evaluate the land cover changes through a comparison of images acquired for the same area at different times. Changes like increased area under cultivation, conversion of annual crop land to horticulture, change in surface water area and levels, afforestation, soil reclamation, etc. could be monitored through satellite remote sensing.

Remotely sensed data acquired from IRS 1C/1D satellite was used as a tool to detect and monitor the changes in the watershed. Peddakalvapalle watershed of Chittoor District, Andhra Pradesh was taken up for the study. The watershed is located between 14°00' and 14°10' North latitudes and 78°35' and 78°45' East longitudes. The average rainfall of the watershed is 730.04 mm and the soil type is red sandy loam.

The satellite data acquired during February 12, 1997 and February 25, 2002 offered a rich source of information about the status and condition of the resources on the watershed landscape. The satellite data analysis was carried out using IBM RS6000 computer system and EASI / PACE software at RRSSC-BANGALORE / ISRO. The watershed boundary was obtained from SOI toposheet 57J/12, based on drainage and contour information. The map was scanned and registered with satellite data.

The satellite data of the watershed for both the periods was classified into different land use/land cover categories using supervised classification by MXL algorithm. The analysis has indicated improvement in the extent of irrigated lands, water bodies and *kharif* season lands. Significant reduction in the area under wastelands was also observed. The area under irrigated lands, water bodies and *kharif* season lands increased by 5.9, 0.21 and 7.98 per cent respectively.

NDVI maps were generated for the study area for the two periods by ratioing of infrared and red bands and its comparison exhibited an increase in the biomass of the watershed. The vegetative vigour/biomass of the watershed was classified into five levels from NDVI analysis. The results indicated that the area under very high, high and medium biomass levels increased significantly by 2.97, 3.88 and 6.7 per cent respectively, indicating more productivity in the region. The area under low vegetation level decreased by 13.59%.

These changes in the watershed can be attributed to various works implemented under watershed development projects like conducting of awareness programmes, practice of soil and water conservation measures, changes in the cropping pattern, introduction of hybrid varieties, use of fertilizers and pesticides.

The productivity of the major crop groundnut increased from 560 to 620 kg per ha. From discussions with the agricultural officers of the watershed it was observed that the socio-economic conditions of the people has increased marginally. Increase in the land value, cattle population, decrease in the migration of the labour was also observed.

The cost of monitoring the changes of land use and biomass changes in Peddakalvapalle watershed by remote sensing and GIS worked out to Rs.7.30 / ha while that of conventional methods was Rs.16.00 / ha. Another, major advantage is no manual surveys could be conducted now for the past periods and could be done only by remote sensing and GIS by imageries of past periods. Similarly, remote sensing and GIS techniques for the present work needed only 30 man-days while that of manual / conventional methods would have needed 328 man-days.

Thus, it was observed that the monitoring of watershed using remotely sensed data is cheap, rapid, accurate and reliable with repetitive coverages. So the planners, decision makers would find adoption of satellite based monitoring and evaluation as a potential, cost-effective and fruitful tool/mechanism.

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